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QUARTERLY

OF THE

National Fire Protection Association

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National Fire Protection Association.

(INTERNATIONAL.)

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Western Actuarial Bureau (Fire)
Western Canada Fire Underwriters' Association.
Western Factory Insurance Association.
Western Insurance Bureau.
Western Sprinklered Risk Association.
West Virginia Inspection Bureau.
Wisconsin Inspection Bureau.

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Reports of fires appearing in the Quarterly *are copies of or extracts from written reports forwarded to the Association. This Association, as a body, is not responsible for the statements or opinions of any of its members.*

A conflagration in the San Lazaro district of Manila recently destroyed twenty-two blocks of bamboo, thatched roofed native houses.
This fire is described in the article on page 124.

Mrs. Shrade expresses sincere thanks to the Fire Department and all those who rendered assistance at the burning of her barn Monday evening.—*Cascade* (Ia.) *Pioneer.*

A conflagration in the San Lazaro district of Manila recently destroyed twenty-two blocks of bamboo, thatched roofed native houses. This fire is described in the article on page 124.

The Quarterly

Vol. 15 October, 1921 No. 2

New Sources of Energy. It is always a matter of speculative interest as to how the fire waste may be affected by new manufacturing processes, the discovery of new chemical combinations for industrial uses, or new applications of existing power. The development of the internal combustion engine, for example, increased fire hazards enormously by promoting the general use of gasoline. Other illustrations of increased fire hazards might be given, over against which may be set the substitution of less hazardous for more hazardous processes in industry, the substitution of water power for coal, etc. Should the new sources of energy the scientists are talking about really emerge from their theories and become factors in the world's life and work, fire hazards might be profoundly affected for better or worse by them also.

There seems nothing necessarily fantastic or chimerical in most of the suggestions brought forward at the international meeting of the American Chemical Society last month in New York, concerning possible sources of still unharnessed power. For the great part, indeed, they are not wholly novel, but the massing of them is impressive. Some of them, such as the winds, waves, and tides, give problems to the engineer rather than the chemist, and it is not to be supposed that the last word has been said in regard to the exploitation of these obvious but elusive sources of energy. One of the most interesting of the new projects is that for utilizing the 30-foot tidal range of the Severn river by a dam 3 1/8 miles long which the British ministry of transport is to undertake.

Undoubtedly ways may be found also to make more effective use of the solar heat which falls upon waste areas like the Sahara, the sands of which receive daily, it is said, the equivalent in power of 6,000,000,000 tons of coal. Moderately successful small scale experiments have already been made. More novel is the proposal by an industrial chemist of Boston, of the utilization of rotation of the earth, which at present is used only for the gyroscope in its various forms. But while the potential power is ample no way is known by which it can be turned to practical account and this proposal is but a suggestion.

More strictly within the chemist's field is the release of the tremendous latent energy of the atom, a sensational illustration of which has lately been given by the discovery of radium. Radium is rare, but science

has discovered that in matter of all kinds there exist atomic forces far transcending the energy derived from the burning of coal or from the most powerful known explosives.

On problems of this kind some of the ablest scientists in many countries are engaged, and while they are chary of prophecy they are working in full faith that with fuller knowledge prodigious new reservoirs of force will be tapped which will not only replace the waning stores of coal and oil but increase prodigiously the power available for driving the world's machinery and make possible many things—in aeronautics for example—for which intense concentration of energy is needed.

* * * * *

The Inflammable Motion Picture Film. Members who have read the Association's annual resolutions as they appear in the *Proceedings* of the last annual meeting have noted by paragraph 10 that its attitude toward the non-professional use of the nitro-cellulose motion picture film has not been modified. This plank in our platform is as follows, (The Association advocates):

10. The adoption of state and municipal laws and ordinances regulating motion picture displays and exchanges; the prohibition, without a standard enclosing booth, of the use of motion picture projection machines in any building unless the film used is of the slow-burning type, and the ultimate substitution in the manufacture and use of motion picture films of the slow-burning type in place of the nitro-cellulose film.

The Executives in discussing this matter informally at the September meeting in New York could see no reason for modification of this very clear and positive position taken by the association. The officers of the Association have been repeatedly importuned by educational agencies (in co-operation with manufacturers of portable projection machines designed for using professional films) to exert their influence with our members to secure a revision of the Association's positive stand against the non-professional use of the gun-cotton film. The principal argument of these agencies and these portable projection machine manufacturers is that a sufficient variety of picture subjects printed on slow-burning stock is not available because the slow-burning films are all of the narrow, non-professional width: too narrow to carry the popular pictures shown professionally.

As a solution of this problem these interests do not move for the printing of the desired pictures on safety stock film of professional width, although it is obviously as easy to produce safety film in one width as in another; they exert their influence to secure their object along what seems to them the easiest way—the attempted breaking down of those safeguards the observance of which by the professional motion picture industry for the past decade has obviated the holocausts originally incident to it.

The argument presented in the states and cities which have laws or ordinances prohibiting the use of nitro-cellulose film in audience rooms without a protecting booth is that the film can be safeguarded in the act of display in a properly constructed portable projection machine. Nothing is said about the hazard of the presence of the film in the building or its storage and handling by non-professional people who are ignorant of its

dangerous qualities, yet it was not in a picture machine at all but in a railway passenger coach that four reels of nitro-cellulose film in non-professional hands caused the death of two and severe injury by burning to thirty-eight people a few years ago.

* * * * *

The Entering Wedge. No great concern was felt among safety engineers when a year or two ago the portable projection machine interests secured a modification of the ordinances of one or two small cities in the Northwest to permit the non-professional use of the inflammable film without a booth. It was assumed that the local politicians had mistaken the voice of salesmen for the voice of the people and that the step backward would soon be retrieved. But when the Industrial Commission of Wisconsin this year, let down the bars for that whole state, and the Pennsylvania Department of Labor and Industry put forward tentative rulings that seemed designed to set aside the State law on this subject the matter took on a more serious aspect. Final action has not at this writing been taken in Pennsylvania where the shadow of the Boyertown horror still hangs over the editorial offices of such newspapers as the *Philadelphia Ledger;* but in Wisconsin the plunge was made in mid-summer. Those interested in the subject should write to the Industrial Commission of Wisconsin, Madison, Wisconsin; and obtain a copy of modification of general order 5539, issued July 12, 1921.

This commission document seems on critical examination a curious one. By it, Wisconsin citizens seeking an education may be exposed to the inflammable film hazard; the Chaplin-Pickford-Arbuckle devotees remain under the protection of the state. The last paragraph of the bulletin carries the threat that if the restrictions are violated by the educators they will have to go back to the protecting booth or safety film. The restrictions limit inflammable film exhibitions to picture machines approved by the Commission installed in factories and offices, or rooms with a floor area not exceeding 1200 square feet; forbid displays oftener than twice a month, and require metal cabinets for storing films not in use.

The first of these restrictions may be observed: the balance of them probably not; they will be increasingly ignored until something happens to stir public sentiment, which is what the Commission most likely has in mind in the last sentence of its bulletin. The document has the tone of political expediency rather than conviction and this may be a sufficient answer to its critics. If the Wisconsin people really wish to expose themselves and their children to this hazard their public servants cannot prevent them and continue in office. The Commission may have good luck and has probably discounted the fact that consequences are unpitying.

* * * * *

The Final Solution. It is fatuous to assume that the hazard of these films is overestimated because no public holocausts have been ascribed to them for a number of years. The gun-cotton film since the tragedies of its beginnings has been reasonably well confined to professional use inside protecting booths, and its handling and transportation professionally systematized. An occasional film-exchange fire alone demonstrates the severe hazard of the material. Here and there

these films are shown without booths in violation of law, but the number actually handled non-professionally is comparatively small. That is the answer to the present feeling of public security from and indifference to this hazard; the hazard has been safeguarded.

But now comes a great state—two great states—which seem willing to abandon this vigilance and admit the nitro-cellulose film to locations and conditions where no commercial interest will look after it; where janitors and school-boys will handle it, ignorant of its nature; where it will lie about on school shelves; in fact the inflammable film is at last to have its innings and demonstrate its power in non-professional life.

Why should this be so? We have the word of the principal manufacturer of picture film in America that the mechanical difficulties originally presented in the manufacture and use of the safety film have been successfully overcome. Why then should it not be universally used and this present hazard eliminated from our public and private life? Why should the motion picture industry place upon state and city officials and departments, underwriters and others the responsibility and expense of safeguarding the lives of the public against a danger which could be so easily eliminated by the industry responsible for it? The added cost of a fragment of a cent a foot for a safe motion picture film is a cynical objection from a business that can award such princely sums to popular actors and clowns.

The final solution of this problem is the substitution of the safety film in both non-professional and professional motion picture service and the efforts of the forces of safety and conservation should be directed to that end.

We believe the Industrial Commission of Wisconsin has made a serious blunder and that the Pennsylvania Department of Labor and Industry is in danger of duplicating it. If the public will demand a safe film for non-professional use it can get it: get it in any width desired: get it with any picture it may ask for: get it with "safety film" inscribed upon its margin so that it may be unmistakably identified by those wishing to rely upon it. With these facts before us we are and shall be morally responsible for any life sacrificed upon the commercial altar of the gun-cotton film.

* * * * *

Wooden Shingle Fire Hazards.

The Railway Fire Protection Association (Member N. F. P. A.) has made an interesting suggestion to its members for consideration by the real estate and contract departments of the railways. It is that, where applicable to local conditions, the following clause be inserted in leases to and agreements with persons or corporations using land belonging to the railways:

"The elevator and other buildings erected by lessee on the above described premises shall be equipped with non-combustible roof and sides, and whenever renewal shall be made of roof or sides on elevator or other buildings on above described premises, such renewals shall also be made with non-combustible materials, it being understood that all shingle roofs shall be replaced within ten years from date first put on. The lessee shall maintain and keep the buildings and surrounding premises in proper, clean, safe and sanitary condition and free and clear of any explosive, inflammable or combustible material which would increase or tend to increase the risk from fire; shall keep the premises surrounding build-

ings free of all litter and vegetable growth, other than lawn grass, which shall not be over three inches high; shall cover the ground space between the inner railroad rail and any grain-loading building with cement, and where buildings are without solid foundations shall cover the openings between foundation walls with iron.

There is nothing unreasonable in this suggestion as both the wooden shingle and dry grass are exceptional hazards along railroad rights of way. The much discussed locomotive spark hazard is not the only culprit and it can be rendered innocuous in many localities by good housekeeping.

* * * * *

An Oil Fire Epidemic. The startling series of oil fires of major importance which have occurred within the past few months gives unusual emphasis to the importance of proper protection for oil storage. That oil storages have not been properly protected is conclusively shown by the enormous money loss of the Warner-Quinlan Asphalt Co. fire in July, and the series of other large oil fires all within a comparatively short period. And when we think of the loss of life involved in these fires, the reported loss of six lives in the Salt Lake City oil fire in June, and sixteen lives in two fires within a month in the same property, the Atlantic Refining Company, Philadelphia, to mention only two, we sense the public demand that this oil problem have immediate consideration, and that vigorous effective measures be taken to combat its fire menace. But careful consideration has been given to this oil problem, and measures for effective protection have already been devised. This epidemic of serious oil fires simply indicates a disregard of well recognized features of protection, a disregard which in some cases can be considered nothing short of criminal.

* * * * *

Protection for Electric Power Stations. The article by Mr. F. A. Allner, on "Fire Prevention in Electric Power Stations from the Operator's Point of View" which appears in this issue of the QUARTERLY, is an especially interesting contribution, in that it considers the subject strictly from the operator's view point, one too often disregarded by fire protection engineers. The electric station operator fears fire, not primarily because of any direct money loss, but because station fires are apt to involve interruption to electric service. And in handling electric station fires, the operator gives first thought to maintaining continuous service, and only secondary consideration to the direct damage by fire.

Mr. Allner's suggested methods for handling fires in electrical equipments are based on a series of tests on large scale apparatus, and include such interesting experiments as the determination of the conductivity of soda-acid extinguisher streams. Some of Mr. Allner's conclusions, especially those with regard to the effectiveness of soda-acid extinguishers on fires in electrical apparatus containing oil, are very interesting and come somewhat as a jolt to our established notions on this subject.

Meeting of Executive Committee.

The usual meeting of the executives following the annual meeting of the Association was held in New York City on September 9th, for consideration of matters referred to the Committee by the Association, for revising the rosters of the various committees where necessary, and for consideration of reports, finances, communications, etc. The following members were present:

Rudoph P. Miller, New York, *Chairman*
A. T. Bell, Atlantic City
D. Knickerbacker Boyd, Philadelphia
J. H. Kenney, Baltimore
H. L. Miner, Wilmington, Del.
Dana Pierce, New York
F. B. Quackenboss, Nashville
W. O. Robb, New York
W. E. Mallalieu, New York, *President*
F. J. T. Stewart, New York, *Past President*
Franklin H. Wentworth, Boston, *Secretary*

It was *voted* to hold the 26th annual meeting of the Association at Atlantic City, N. J., May 9, 10, and 11, 1922. The President, Secretary, Chairman of the Executive Committee, and A. T. Bell of Atlantic City were named as the Program Committee.

F. B. Quackenboss of Nashville and Jay W. Stevens of San Francisco were selected to complete the Nominating Committee, 1922.

The status and responsibilities of auxiliary members were discussed without action.

Items from Annual Meeting.

(a) The recommendation of the Committee on Docks, Piers, and Wharves for the provisions of regulations for the protection of openings in walls and partitions of docks, piers, and wharves was referred to the Committee on Protection of Openings in Walls and Partitions in conference with the Committee on Docks, Piers, and Wharves.

(b) It was *voted* to ask the Committee on Docks, Piers, and Wharves to obtain and tabulate all sources of information on the subject of concrete construction of docks, piers, and wharves for the guidance of the Executive Committee in providing for the preparation of the specifications on this subject requested by that Committee.

(c) The Ordinance governing Inflammable Liquids was *adopted* with the following revisions made by the Committee on Laws and Ordinances in the text submitted to the annual meeting. (See Proceedings, p. 65.)

Section 2. Classification of Inflammable Liquids: under "representative examples" transfer *acetone* from Class II to Class I, and add to the Class II list, *ethyl acetate* and *methyl acetate.*

Section 21. Exceptions: add at end of section "Garages and Dry Cleaning only as given in Chapter I and Sections 38, 39, 40, 41, 42, 43, 44, 46, 50, 51, 52, 55, 56, 57, 60, 61, 63, 64, 65 and 66.

Section 29. Change heading to "Requirements for special storage rooms *or buildings*" and insert the words "or buildings" in first line after the words "special rooms."

Section 30. Storage of Class I liquids: add the following paragraph:

In manufacturing plants, the chief of the fire department may permit the storage of Class I liquids in portable wheeled tanks as described in Section 43, where the nature of the business requires such storage and the discharge therefrom. Such wheeled tank shall be used only in special rooms or buildings as given in Section 29.

Section 46. Underground Storage Limited: substitute the following text:

Section 46. Tanks located underground shall have top of tank at least three feet underground and below any piping to which the tanks may be connected, except, in lieu of the three feet of earth, tanks may be buried under 18 inches of earth and a cover of reinforced concrete at least six inches in thickness provided, which shall extend at least one foot beyond the outline of the tank in all directions, said concrete slab to be set on a firm, well tamped earth foundation.

(a) Tanks shall be securely anchored or weighted in place to prevent floating.

(b) Where a tank cannot be entirely buried it shall be covered over with earth to a depth of at least three feet and sloped on all sides not less than three to one.

(c) If a tank cannot be set below the level of all piping to which it is connected, satisfactory arrangements shall be provided to prevent siphoning or gravity flow in case of accident to the piping.

(d) Tanks shall be set on a firm foundation and surrounded with soft earth or sand tamped in place, or encased in concrete not less than 12 inches thick with a 6-inch air space on sides between the tank and the insulation.

(e) When located *underneath a building* tanks shall be buried with top of tanks not less than two feet below the level of the floor. The floor immediately above the tanks must be of reinforced concrete at least nine inches thick or some other type of construction of equivalent strength and fire resistance, extending 12 inches beyond the outlines of the tank in all directions and provided with ample means of support independent of any tank.

Tank may have a test well, provided test well extends to near bottom of tank, and top end shall be hermetically sealed and locked except when necessarily open. When tank is located underneath a building, the test well shall extend above source of supply. The limit of storage permitted shall depend upon the location of tanks with respect to the building to be supplied and adjacent buildings, as follows:—

Under "maximum capacity of tanks for underground storage" in Section 46, change flash point at top of both columns of table from 150° to 100° F.

(d) The revised Regulations for the Installation and Use of Internal Combustion Engines submitted to the annual meeting (see *Proceedings*, p. 343) were *adopted* with changes in the text recommended by the Committee on Gases.

(e) The resolution adopted by the annual meeting recommending the appointment of a committee "to study, measure and define the fire hazard of various occupancies in terms of probable duration of fire" was referred to the Committee on Building Construction for discussion and expression of opinion as to the procedure best calculated to achieve the result desired.

The field and scope of the work of the Committee on Manufacturing Risks and Special Hazards was considered and its production of monographs on special industries endorsed and commended. It was *voted* to request this Committee to complete its work of preparing regulations for

the protection of fire hazards incident to the use of Volatiles in Manufacturing Processes and the Installation of Foam Extinguishing Systems and to consult the Executive Committee concerning the preparation of regulation on any other subjects.

The Budget for the fiscal year submitted by the Treasurer was amended and adopted.

It was *voted* inexpedient to accept the invitation of the National Conservation Association to become a member of that body.

A. M. Schoen, Chairman of Committee on Protection against Lightning, was appointed to represent the Association on the Sectional Committee of the American Engineering Standards Committee charged with the preparation of a safety code for lightning protection of which the U. S. Bureau of Standards and the American Institute of Electrical Engineers are joint sponsors.

An Executive Committee resolution was passed upon the death of Vice-President William C. Robinson, and a Committee consisting of Vice-President H. O. Lacount and Secretary Franklin H. Wentworth was appointed to present a memorial resolution to the Association at its next annual meeting.

The matter of the publication by the Association of a book on Dust Explosion Hazards was favorably considered and referred to the Secretary.

The matter of promoting a campaign by the Parent-Teacher Association for the safeguarding of schoolhouses against fire was favorably considered and the Secretary authorized to continue negotiations with that object.

Communications from committee chairmen and various members were considered in connection with revisions of committee rosters, the changes in which will be shown in the forthcoming Year Book.

Smoking in Factories.

Extract from letter of J. E. Florin, Superintendent of Fire Prevention, Industrial Commission of Wisconsin. (Member Committee on Public Information, N. F. P. A.)

As to the matter of smoking in factories, we doubt very much that anything could be accomplished by law, as this is one of those personal matters which it would be almost impossible to enforce. This matter must be reached through education and through personal efforts with factory management. For a number of years we have distributed "No Smoking" signs in this state and the demand for the same has steadily increased, and conditions along that line in factories, mills, and elevators are improved.

In our various codes we have just one provision affecting smoking and that is to prohibit the same in moving picture booths, and I am safe in saying that on this point there are perhaps more violations of this order than any other order the Commission has promulgated.

The Protection of Historic Public Buildings.

2. The Old State House, Boston.*

Introduction.

One of the most famous of Boston's historic buildings is the Old State House, intimately associated with many stirring events of America's early history. As John Adams said: "Then and there was the first scene of the first act of opposition to the arbitrary claims of Great Britain. Then and there the child Independence was born."

The old building, a priceless and unreplaceable monument, still stands today with no special fire protection except hand extinguishers and not protected by automatic sprinklers. Sprinklers are not installed because of fear of water damage. There is no reason why sprinklers should not be installed in at least a part of the basement, and effective fire-stops inserted in a few vital but inconspicuous places. It may be said, however, that excellent housekeeping minimizes the possibility of fire from any ordinary cause such as "matches-smoking." That repeated attacks of fire on the Old State House have been defeated is evidence of good fortune and excellent work of the fire department, rather than of precautions against fire. The Old State House and its predecessor have been visited four times by fire, not counting the Great Boston Fire of 1872 which menaced the building but was fortunately stopped before it reached State Street. The first Town House, predecessor of the State House on the same site, built in 1658, thirty-eight years after the Pilgrims landed at Plymouth, was completely destroyed in the conflagration of 1711. The present building, erected immediately thereafter, has been damaged by fires in 1747, 1832, and 1921. The fire of 1747 left only the brick walls standing; the fires of 1832 and 1921 were extinguished with minor, though serious, damage.

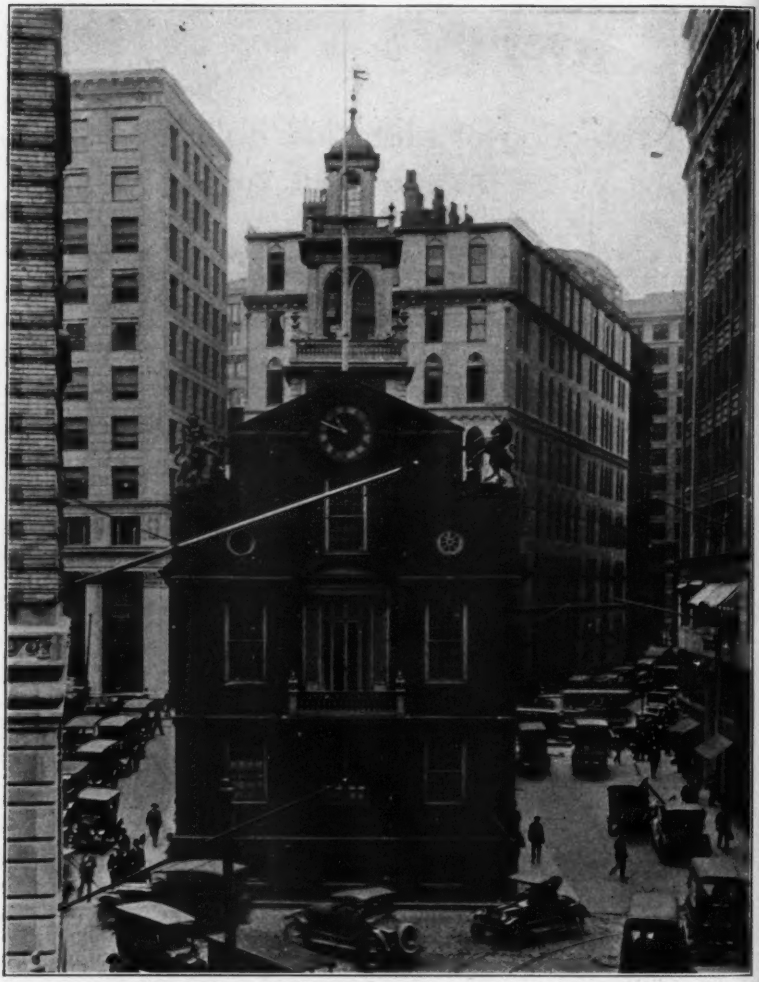
The First Town House.

In 1656 the town of Boston, then of less than 4000 population, received a legacy of £300 from a Captain Robert Keayne, which together with money, materials and labor obtained by popular subscription, was used for the construction of a Town House, the predecessor of the present Old State House. The Town House was used for the administration of public affairs, for the housing of a library, and on the first floor were a number of small shops or stalls, which were rented to augment the town's revenue.

The Fire of 1711.

The Town House was totally destroyed in the great fire of October 2, 1711, which Hutchinson thus describes in his History of the Colony of Massachusetts Bay:

*NOTE: This is the second of a series of articles on the fire protection of important public buildings of historic interest. The third article will appear in the January QUARTERLY.—*Ed.*



The Old State House as it stands today, a monument to the stirring events of Boston's early history.

It broke out in an old Tenement within a back Yard in Cornhill near the First Meeting House, occasioned by the carelessness of a poor sottish Woman, one Mary Morse, by using Fire near a parcel of Ocum Chips and other cumbustible Rubbish. All the houses on both sides of Cornhill from School Street to what is called the stone-shop in Dock Square, all the upper part of King Street on the South and North Side, together with the Town House and what was called the Old Meeting House above it, were consumed to ashes.

Boston's First Town House, built in 1658 on the site of the present Old State House. No original drawing existing, this drawing is made from the builder's specifications. This building was detroyed in the conflagration of 1711.

When the next morning dawned, the people of Boston realized that the very heart of the town had been eaten out by the fire which had consumed about one hundred buildings, and made one hundred and ten families homeless.

It seems strange to us who live in the twentieth century that the Rev. Increase Mather believed that this great Boston fire was a judgment of God for the wickedness of the people. He said in a sermon which he preached immediately after the fire:

> But has not God's Holy Day been prophaned in New England? Has it not been fo in Bofton this laft fummer, more than ever fince there was a Chriftian here? Have not burdens been carried through the ftreets on the Sabbath day? Have not Bakers, Carpenters and other tradefmen been employed in fervile work on the Sabbath day? When I faw this . . . . my heart faid Will not the Lord for this kindle a fire in Bofton.

Immediately after the fire steps were taken to replace the building, and in 1713 a new Town House on the same site was completed and ready for occupancy. The brick walls of this building still stand in the Old State House of today, though since 1713 many structural changes have been made.

During the period 1713-1747, many interesting events took place in the building. The Governors of the Province of Massachusetts Bay administered their official duties in the Council Chamber; here the famous expedition which captured Louisburg from France in 1746 was organized; and here the people of the colony successfully protested against the seizure of some of their number for service in the British navy.

The Fire of 1747.

On December 9, 1747, the building was destroyed by fire, which left only the brick walls standing. The fire is described by the *Boston Weekly News Letter* of December 10, 1747:

Yefterday morning between 6 & 7 o'clock we were exceedingly furprifed by a moft terrible Fire, which broke out at the Court Houfe in this Town, whereby that fpacious and beautiful Building except the bare outward Walls, was entirely deftroyed. As the Fire began in the middle or fecond Story, the Records, Books, Papers, Furniture, Pictures of the Kings and Queens, &c., which were in the Council Chamber, the Chamber of the Houfe of Reprefentatives and the Apartments thereof, in that Story, were confumed; as were alfo the Books and Papers in the Offices of the upper Story: Thofe in the Offices below were moftly saved. In the Cellars, which were hired by feveral perfons, a great quantity of Wines and other Liquors were loft. The publick Damage fuftain'd by this fad Difafter is inexpreffibly great, and the Lofs to fome particular Perfons, 'tis faid, will amount to feveral Thoufand Pounds. The Vehemence of the Flames occafion'd fuch a great Heat as to fet the Roofs of fome of the oppofite houfes on Fire, notwithftanding they had been covered with Snow, and it was extinguifhed with much Difficulty. How the Fire was occafion'd, whether by Defects in the Chimney or Hearth as fome think, is uncertain.

The brick walls withstood the fire so well that in 1748, when the Town House was rebuilt, they were used again. The rebuilt structure is described by a traveller who visited Boston in 1750, as follows:

They have alfo a Town Houfe, built of Brick, fituated in King's ftreet. It's a very Grand Building, Arch'd all Round, and Two Stories High, Safh'd above; its Lower Part is always Open, defign'd as a Change, tho' the Merchants in Fair Weather make their Change in the open Street at the Eaftermoft End. In the upper Story are the Council and Affembly Chambers &c. It has a neat Capulo. fafh'd all round, and which on rejoycing days is Elluminated.

The Old State House is associated with many important events during the period of the Revolution. A few of them are as follows; in 1770, the Boston Massacre, Samuel Adams demanding the withdrawal of the British troops from Boston and the trial of Captain Preston and his soldiers who participated in the massacre; in 1776, the Declaration of Independence was proclaimed from the east balcony. The year 1782 was made memorable by a reception in honor of the French fleet and army, which were on their way home to France. In 1783 the Treaty of Peace was likewise proclaimed to a great multitude gathered in the street below. And to crown all, "Here the child Independence was born."

In 1798 the Old State House was abandoned by state officials, when they took up quarters in the new State House on Beacon Hill. After this, and until 1881, the building was leased for commercial purposes, and considerably altered. These vicissitudes need not be dwelt on here.

The Fire of 1832.

In 1832 the "City Hall," as it was called at that time, narrowly escaped destruction by a fire which is described by a contemporary as follows:

On the 21st of November, 1832, about five o'clock in the morning, this ancient building, the scene of so many interesting events, again took fire from an opposite (burning) building, under the stool of one of the Lutheran windows, which soon communicated with the under side of the roof, and had it not been for the uncommon exertions of the Fire Department, it must have been completely prostrated in a little time. As it was, however, the damages were easily repaired. The appropriation of the Council for the purpose was $3,500.00. No papers of importance

The fire of 1832, when the roof of the Old State House was ignited by brands from an exposure fire across the street. This picture is taken from an old Fire Department certificate.

were lost, and the curious records of the city, from its first settlement, for a third time were safely rescued from a devouring element.

In 1881 the removal of the Old State House was seriously threatened, but after continued agitation the city government appropriated $35,000, which was used to restore the building to its original condition in 1882. Further restorations were made in 1908 and 1909. Since 1882 the building has been in the custody of the Bostonian Society, and occupied by this historical society as headquarters, museum and library. A minor portion of the basement of the building has since been appropriated for use as a subway station, but legislation prevents any further encroachments.

The Fire of 1921.

During the original and subsequent restorations it is evident that little or no provision was made for fire protection, except careful housekeeping by the Bostonian Society, for a fire, which started from unknown cause (probably spontaneous ignition) in a concealed space in the first floor, on the evening of April 13, 1921, spread rapidly up through concealed

Courtesy of The Boston Globe

A night photograph taken during the fire which threatened to destroy the Old State House, April 13, 1921. This fire was extinguished with comparatively little damage, through the effective work of the Fire Department.

wall spaces, and was discovered only when a passerby saw smoke issuing from upper windows. The Fire Department, responding promptly attacked the fire under instructions to use as little water as possible, and deserves great credit for getting it under control with comparatively small damage to the priceless relics in the building. The Protective Department has also been highly praised for its work in this connection. The wooden interior, the wooden tower not cut off, and the concealed spaces between wood lath and outside brick walls, made the work of the fire fighters difficult. As it was the damage was considerable, being estimated at $10,000.

Present Fire Protection.

In the restoration of the Old State House after the fire of April, 1921, at this writing nearly completed, brick fire stopping is being inserted in the walls at floor levels, and other improvements are being made. But for protection against fire the Old State House must rely principally on the very careful housekeeping of the Bostonian Society.

The portion of the basement used as a subway station is effectively cut off from the balance of the building, but the boiler room in a sub-

Courtesy of The Boston Transcript

The attic of the Old State House after the fire of April 13, 1921.

basement, while it has a heavy concrete ceiling, communicates directly with the basement through a thin wooden door. No portion of the building is sprinklered, not even the basement, because of fear of water damage to the many relics, paintings, and other objects of historic interest. There is a large open stairway in the center, separated from the wooden tower above only by a thin wooden door. The building has a slate roof, and is isolated, but the wooden tower has no outside sprinkler protection, and might be ignited by a serious exposure fire, though the construction of nearby buildings is fairly good. The building is open to the public, but "no smoking" rules are rigidly enforced.

To summarize, it may be said that the vigilance and good housekeeping of the Bostonian Society may be counted on to prevent fire from any usual or ordinary cause, but in the case of a fire starting from any cause not under the control of the occupants, such as the fire of April 13, 1921, there is nothing to save the old wooden interior from rapid destruction, except prompt and efficient work by the Fire Department.

NOTE: Much of the material in this article, including photographs, where not otherwise credited has been furnished through the courtesy of the Bostonian Society, and Mr. Allan Forbes of the State Street Trust Co. Some of the text, especially the quotations, has been taken from "The Old State House" by Charles F. Read, clerk of the Bostonian Society.—*Ed.*

Spray Systems for Pulp Wood Piles.

By C. W. Mowry, Director of Laboratories
Associated Factory Mutual Fire Insurance Companies.
(Member N. F. P. A.)

The continual wetting of pulp wood as a means of fire prevention was advocated in an article by F. J. Hoxie on "Log Piles: Their Hazards and Protection," in the QUARTERLY for July 1920 (Vol. 14, No. 1, page 81). Keeping the wood wet, it was suggested, would also retard rotting of the logs and would improve the quality of certain kinds of pulp. The October 1920 QUARTERLY (Vol. 14, No. 2, page 124) contained a brief description of an experimental spray system at the Lake Superior Paper Company, Sault Ste. Marie, Ont., which was the first concern to apply this idea practically. The results were so promising that the practice was continued for a second season, using commercial spray nozzles. This pile with the spray system in operation is shown in Figure 1.

Fig. 1. 30,000 cord pile of unbarked spruce logs. Lake Superior Paper Co., Ltd., Sault Ste. Marie, Ont. Continual spray system of 300 nozzles. Prevents fire and improves wood for barking.

The pile contains 30,000 cords of unbarked spruce and is protected by three hundred nozzles, those on the upper half of the pile discharging about one gallon per minute and those on the lower half about three quarts per minute. The heads are spaced at 30 ft. intervals on branch lines 20 ft. apart fed from a supply line around the base of the pile. Water is furnished by two centrifugal pumps in series giving a pressure of about 100 lbs. per sq. in. and delivering about 300 gallons per minute to the nozzles. The spraying is constant twenty-four hours per day, and wets the surface of the wood with a heavy mist. The distribution is assisted by a breeze which prevails almost continually in this locality,

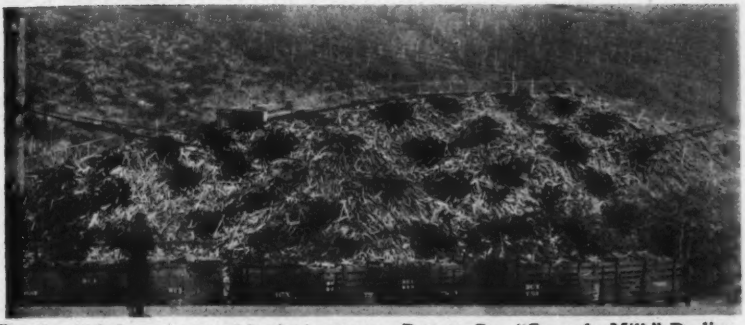


Fig. 2. 27,000 cord pile of barked spruce. Brown Co., "Cascade Mill," Berlin, N. H. 2 quart nozzles, 30 ft. apart. Dark spots are wetted areas after two months continual spraying, showing need of closer spacing and larger nozzles.

although on calm hot days dry spots appear on the surface between the nozzles. The management states that the wetting considerably improves the wood for barking and that the condition of the logs throughout the pile is uniform with a moisture content in the chips of about 55%. The strength of the digester liquor can consequently be kept practically constant instead of being continually changed to suit varying wood.

The effect of spray on the moisture content of pulp wood has been carefully studied by E. Sutermeister, Chemist, S. D. Warren Paper Co., whose experiments are described in the December 22, 1920, edition of *Paper*. Briefly stated, he finds that the moisture delivered by the nozzles was more than necessary to replace the normal evaporation within the wetted areas and that the logs continually subjected to the spray became uniformly wet with a moisture content ranging from 52% to 60%. Where the spray fell only part of the time, the logs took up considerably less moisture. While it was difficult to accurately determine conditions in the interior of the pile, it was found that the moisture reached the bottom of a pile 75 ft. high, and also that the wood within a few feet of the ground was more moist than in the middle and upper sections. Mr. Sutermeister reported that careful inspection of the wood in this pile where it was normally very wet, showed the logs to be superficially slimy and nearly black, but in very good condition. The state of the logs as well as of the chips prepared from them proved that the greater part of the wood was sound. Very few pieces could be found which were soft enough to allow a knife blade to be driven into them more than a quarter of an inch.

The relation of the moisture content of wood to its decay with special reference to the spraying of log piles is being carefully studied by Mr. Walter H. Snell, Assistant Professor of Botany at Brown University and formerly Forest Pathologist of the United States Department of Agriculture. The results of the first part of his investigation on loblolly pine and Sitka spruce were published in the *Pulp and Paper Magazine* of May 19, 1921. Loblolly pine has a density practically the same as poplar, balsam and red spruce, and hence it was concluded that the relation of

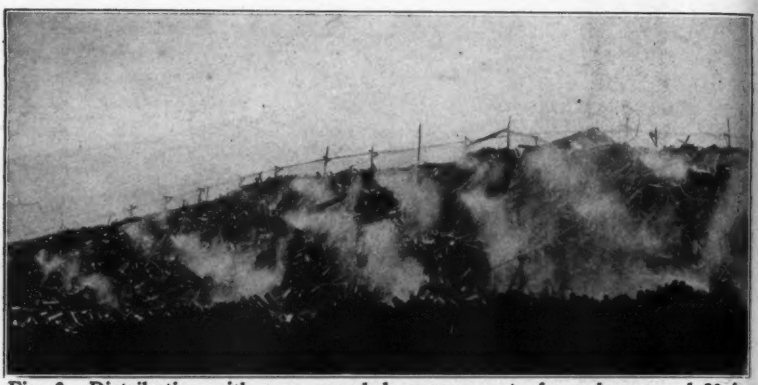


Fig. 3. Distribution with recommended arrangement of nozzles spaced 20 ft. apart, 4 quart heads on upper half of pile and 3 quart heads on lower half. 20 lbs. pressure at top.

the moisture content to decay in this wood would be applicable to pulp wood. The greatest amount of decay occurred with moisture contents between 33% and 42%. The amount decreased from this point up to 50% where there was very little decay, and none occurred at 60%. Mr. Snell's experiments with five different fungi, four of which grow on pulp wood, show that a moisture content of 60% in log piles will eliminate all danger of serious loss from decay.

In view of the encouraging results obtained at the Lake Superior Paper Company and the favorable opinions of investigators regarding the prevention of decay, the Brown Company installed spray systems on three of their log piles, two at Berlin, N. H., and one at La Tuque, P. Q. On the pile which was first equipped, two-quart nozzles were used 30 ft. apart, with the result that dry spots were left between the nozzles except on windy days. This is clearly shown in Figure 2.

The Brown Company co-operated with the Factory Mutual Laboratories in tests on a section of this log pile comparing different types and sizes of nozzles at various spacings. With the two quart per minute nozzles spaced 30 ft. apart, the wetted areas directly surrounding the nozzles were oval and from 15 ft. to 20 ft. long. In the center of these areas the wood was dripping wet; beyond this it was glistening wet and at the outskirts it was merely damp. Between the wetted areas, the wood was apparently dry on the surface, and the punk wood, chips and pieces of bark, which are scattered more or less throughout this and most pulp wood piles, were dry enough to be easily ignited. The dark spots in Figure 2 are the wetted areas to which reference has just been made.

The spacing of the nozzles was next reduced to 20 ft., which, as expected, decreased the dry area but did not eliminate it; and three and four quart nozzles were then tried at various heights above the pile. A distribution which was apparently satisfactory even on calm days was obtained with 20 ft. spacing, using four quart heads on the upper half and three quart heads on the lower half of the pile, with a pressure of not less

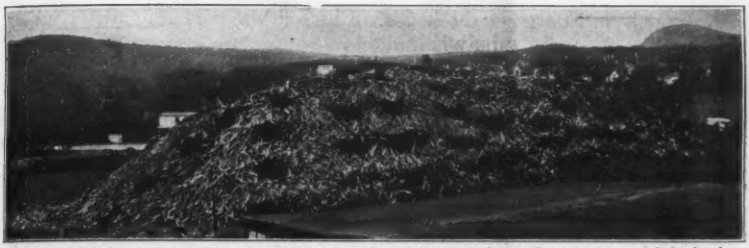


Fig. 4. Left end of pile has 2 quart heads spaced 30 ft. apart, which is inadequate. Extreme right end has 3 and 4 quart heads spaced 20 ft. apart as shown in Fig. 3.

than 20 lbs. at the highest nozzles. A view of this last arrangement is shown in Figure 3. A comparison between the results obtained with the 30 ft. spacing using small heads and the 20 ft. spacing with larger heads is shown in Figure 4. These tests confirm the experience of the Groveton Paper Company, Groveton, N. H., where the first installation consisted of two quart heads 30 ft. apart, but the management quickly appreciated that this was not adequate and installed intermediate branch lines.

Judging from the distribution tests at the Brown Company and the experience at this and several other paper mills, the following general recommendations are made for installing spray systems on log piles to care for the worst conditions on calm hot days when the possibilities of fire are greatest.

1. *Nozzles.* Nozzles should be spaced 20 ft. apart in each direction and preferably staggered, with one row of nozzles directly above the log conveyor, when one is used, to wet the accumulation of fine material directly under the conveyor trough. The 20 ft. spacing enables the piping to be used in standard lengths without cutting. One gallon per minute heads (rated at 50 lbs. pressure) should be used on the upper half of the pile and three quart nozzles on the lower half.

2. *Piping.* Only galvanized iron piping should be used. One mill had unsatisfactory experience with plugging of the nozzles due to the use of black iron pipe and will probably have to repipe the entire equipment. To simplify the installation and the reclamation of piping each year, a standard size of ¾ in. pipe is recommended for the branch lines and 2 in. pipe for the main feeder, taking the branch lines from the top of feeder to minimize the possibility of dirt getting into the branch lines. For piles with the ridge fairly level, as when stacked from a conveyor, it will be most economical to run the feed line along the top with branch lines extending down the pile. Where the wood is piled with a stacker, the ridge is uneven and the best arrangement is to run the feed line around the base of the pile with the branch lines running upward. The feed line can then remain in position when the pile is removed each season. The branch lines with either arrangement can be supported on small crosses of boards and should be about 3 ft. above the wood near the top of the pile and from 5 to 6 ft. above near the bottom, screwing the nozzles upright directly into tees in the branch lines.

3. *Water.* Care should be taken to use clean water free from sedi-

ment which will obstruct the heads. Filtered water is often available at paper mills, but if the supply is limited fine strainers can be obtained from the manufacturers of the nozzles. Blow off valves should be arranged at the ends of the feed lines to blow out the dirt. A water pressure of at least 20 lbs. per square inch at the heads should be maintained at the top of the piles.

4. *Cost.* For estimating purposes, from 12 to 15 nozzles should be allowed per 100 cords of wood. The cost, including materials, labor, pump and motor, will range at present market prices from $14 to $17 per nozzle when first installed. All of the material is reclaimed each year, and the annual labor expense of repiping will be something less than $3 per nozzle.

Manila Conflagration.

Report by J. Fred Dow.
With E. E. Elser, Manila.
(Member N. F. P. A.)

On April 1, 1921, there was a serious conflagration in the district of San Lazaro, Manila, where some twenty-two blocks were completely cleared of structures. This fire, presumably caused by carelessness, started at about 4:45 P. M. and was not extinguished until close on midnight. Had this fire happened during the night the chances are that the damage would have been considerably greater, and several blocks on the west side would undoubtedly have been completely destroyed. The probability is that the fire might have spread until stopped by Manila Bay, which is situated some two and a half miles away. In the San Lazaro section the majority of the buildings were of light construction, bamboo sides and floors, with thatched roofs. The fire department was quite unable to cope with the flames, as about an hour after the fire started a strong wind from east to west got up, and it was with difficulty that several of the fire engines which were in the path of the fire were saved. Many lengths of hose were destroyed.

The effect of the fire on bamboo rafters and beams is peculiar, inasmuch as immediately same become ignited the air within expands and bursts with a report like a gun, sending small pieces of flaming bamboo into the air in all directions; so that while the firemen were busy in one particular block the wind carried these sparks completely over the block and before anything could be done, the houses situated 200 or 300 feet from the burning buildings started to blaze. There were a few frame houses with galvanized iron roofs, but it was impossible to do anything to save these structures, as immediately the hose was laid on from any hydrant the firemen had to uncouple and get out to avoid being trapped between two blazing blocks. I, personally, saw a church of frame construction, with galvanized iron roof, some fifty (50) feet in height, completely demolished within five minutes, and the heat was so intense that

The thatched roofs and bamboo construction of the Philippines are even more hazardous than the wooden shingle, in the spread of conflagrations. The building at the left is typical of construction in the district destroyed by the Manila conflagration.

the firemen could get nowhere near the buildings actually in flames.

The total loss to the community is estimated at $1,500,000, while the Insurance Companies were only interested to the extent of $140,000, which in itself is sufficient to show that conflagrations were expected in this quarter. During one portion of the conflagration the fire actually jumped from the light material houses to strong material houses (constructed of brick below and wood superstructure with galvanized iron roof) over a distance of at least 100 feet.

This district has been burned up on two previous occasions, and the general construction has been gradually improved on Rizal Ave., but unfortunately the construction on the interior blocks had not altered to any great extent from the light materials formerly used. So far as can be ascertained there were two lives lost in this fire, while animals of every description were burned to death. At the time of writing (June 21, 1921) this district is being reconstructed of frame buildings with hard roofs, and the owners of the houses destroyed are camping out in vacant lots around the devastated area.

It is customary for the natives to do their cooking in open earthenware vessels without any smokestacks, or proper stoves, and it is presumed that through carelessness one of these earthenware vessels must have been turned over and the burning embers scattered on the bamboo floor and, before anything could be done to stop the initial outbreak, the whole house was in flames.

On account of this district being occupied by the working class of natives, it has been impossible for the Municipal Board to insist on strong

Ruins in the devastated San Lazaro district of Manila, showing wreckage of galvanized iron roofs. The fire department was able to make a more effective stand when the fire reached this type of construction. The fire was stopped at the buildings shown in the background.

materials being used in the general construction, but after this fire the Board has issued an ordinance prohibiting the use of light materials in the majority of blocks which were destroyed on the first of April, but whether they will be able to maintain the general construction is a question that time only can determine. Should the construction be in accordance with the recommendation given by the Municipal Board, the chances of a conflagration similar to the one above described are remote, as the firemen will have considerable assistance in fighting fires of this class, if the sparks from the light material houses alight only on iron or non-combustible roofs.

NOTE: Report of the Chief of the Manila Fire Department for 1920 indicates an up-to-date fire fighting organization, motorized throughout. The total loss for the year was $2,087,094, a per capita loss of $6.40.—Ed.

Fire Prevention in Electric Power Stations from the Operator's Point of View.

By F. A. Allner, General Superintendent
Pennsylvania Water and Power Co.
(Member N. F. P. A.)

Fire hazards in large electrical stations differ somewhat from those met with in the average industrial plants in that the original cause of fire is usually an electric short circuit or over-voltage phenomenon, and that the damage from fire is only in small part a direct material loss, the major part being a loss due to failure of electric service, involving at times other indirect losses to hundreds of industries and private consumers, who are dependent upon continuous delivery of electrical energy for daily use.

That the direct material loss may be relatively small compared with indirect loss in operation and to business prestige, will be appreciated when considering an internal short circuit in a large hydro or steam generator where the heat of the arc may have damaged only one or two coils and melted a few laminations during the few seconds or perhaps fraction of one second that the arc lasted, but where the service in a large portion of the distribution net may have been interrupted and where the repair work may require several weeks or months, during which time the loss of revenue in a single day due to reduced output or efficiency may equal the total material damage of the breakdown.

Fire hazards in electrical stations, including therein any occurrence of electrical short circuit, accompanied by an arc or high temperature and potential danger of fire, may be classified for the purpose of our discussion of fire prevention according to origin or nature of equipment involved in the following groups:

1. Ordinary fire hazards from waste, gasoline and other materials, similar to the hazards in the average industrial buildings or storerooms.
2. Short circuits on switchboard panels, cables, control wiring, bus bars, etc., with little or no inflammable materials exposed in the vicinity of the arc.
3. Rotating electric machinery such as generators, rotary converters, frequency changers, motors, etc.
4. Power Transformers.
5. Oil switches.
6. Electrolytic lightning arresters, induction regulators, potential transformers and other auxiliary apparatus containing insulating oil.

1. Common Hazards.

This first mentioned group of fire hazards is the one causing the least concern in modern electrical stations that are maintained at the high standard of efficiency and cleanliness, that is characteristic of the central station industry of today. The preventive measures in that respect are identical with the well known Underwriters' rules. Gasoline,

kerosene, or other inflammable liquids should be kept only in small quantities in the stations, using only approved types of safety cans as containers. Accumulation of waste and rubbish should be avoided. The prescribed routine work for each working shift should include an inspection of even the remotest places of the station building once every hour by one of the operating attendants.

Good illumination and cleanliness should be maintained throughout the station. If smoking is permitted under the station rules, cuspidors should be placed liberally at convenient places on the operating floors and the promiscuous throwing away of matches or cigarettes should be dealt with as a serious offence. The formation of explosive gas mixtures in confined spaces should be avoided, and wherever possible, processes that have a tendency to develop inflammable gases such as washing of filter bags with gasoline, or the cleaning of machinery with inflammable liquids should be carried out in an open space, or still better, outside of the buildings.

As a rule, an automatic sprinkler system is not suitable for electric station buildings, except possibly in such portions of the building as are entirely separated from high voltage compartments — as for instance in small storerooms which are partitioned off from the rest of the structure. While most of the small fires, due to the lack of combustible material nearby, can be suppressed successfully with the standard size chemical extinguishers, in many stations water mains are laid throughout the building, with hose connections and glass encased emergency valves at suitable places. An ample gravity storage supply of water should be provided.

2. Short Circuits on Switchboard Panels, etc.

Fires that are started by accidental arcs or grounds and low resistance heat on low tension buses or wiring, as a rule, can be easily extinguished with sand or small sized chemical extinguishers. The fire hazard itself is small on account of the absence of major inflammable materials in the vicinity, but the disturbing effect on system operation in many instances is not negligible because such defects may occur on excitation bus bars of generating stations, on control wiring, station auxiliaries, etc., where they strike at a vital part of the whole system. Aside from careful electrical layout, employment of first class materials, routine inspection in operation and periodic measurement of insulating resistance, special precautions should be taken against accidental arcs, such as covering exposed low tension copper bars with insulating tape, enclosing the space back of switchboard panels with metal screens, arranging protection against falling objects from floors above or against contact with tools or other objects carried by workmen in nearby passageways, guarding the wiring against water, air or steam leaks, etc.

3. Rotating Electric Machinery.

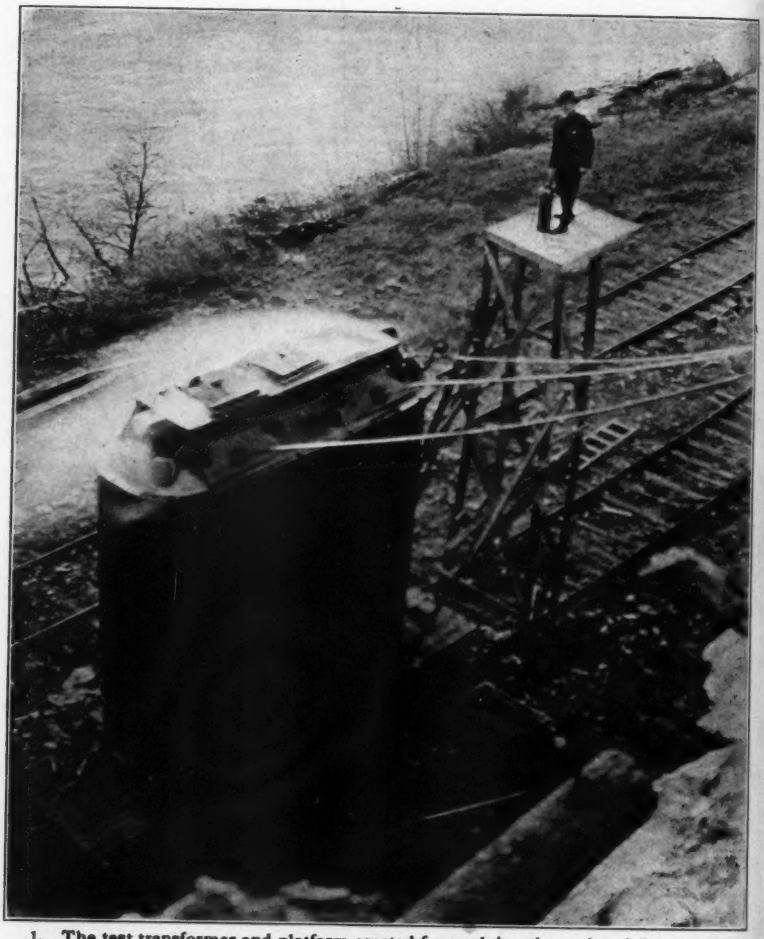
Fire hazards in rotating electric machinery are generally caused by electrical or mechanical breakdowns. It is, however, not beyond the range of possibility that frictional heat or sparks, due to accidental rubbing contact of rotating parts, may start an internal fire. Some of the mechanical breakdowns, such as the loosening of lamination wedges or other improperly secured parts that are forced against high tension windings and damage the insulation, will easily cause a short circuit, followed by

fire. Among the purely electrical breakdowns, weakened insulation, due to high temperatures, over-voltages, and deterioration of dielectric strength, is the most frequent cause of short circuits and fires in rotating electrical machinery.

The first steps to be taken on any kind of breakdown in electrical apparatus should be the disconnection of that apparatus from the rest of the system, the complete withdrawal of potential, and the quick shutting down of the rotating machinery by cutting off the driving power, and in case of large apparatus, by applying air brakes. In recent years, the standard practice has been developed to equip large electrical machinery with so-called balanced type of protective relays, which energize the trip circuits of oil switches and field breakers without time delaying relays in event of internal breakdown. As a rule, the only combustible material in rotating electrical machinery is the insulation of rotor and stator windings. If the arc is permitted to hang on and produce great heat inside of the machine, this material, aided by the fanning action of the rotor, may burn for a long time and destroy not only the windings but also the laminations, and distort machined and fitted metal parts of the frame and supports, requiring then very extensive and time consuming renewals, where the waiting for spare parts from the factory often is the limiting feature in the time required for completion of the repair work.

It goes without saying that after the electrical "killing" of the apparatus the quick extinguishing of the fire is of prime importance. Various schemes have been tried out in recent years, using water, steam or carbon tetrachloride, conducted in pipe lines with suitable nozzle openings along the circumference of the armature, where the steam of liquid would impinge under pressure against the end turns of the armature windings. The present tendency seems to favor water as against steam or carbon tetrachloride, although not sufficient comparative data are available from actual fires to definitely support water as the best choice. The former objection against water, that it was feared to damage the insulation of the unburned coils, has been withdrawn, as it was found that modern insulated coils soaked in water for a short time will regain full insulation resistance again after a few hours of drying. Great care must be taken that water is not turned on accidentally while the machinery is in normal operation. A double system of valves, one of which is enclosed in a glass casing which must be broken first before turning on the water for emergency use, is recommended. In order to insure against leakage, or at least detect same easily, a small bleeder opening should be provided in the short pipe connection between the two valves where leakage would be visible from the outside.

On high speed rotating apparatus natural ventilation, as a rule, does not provide sufficient air cooling, and an external blower system is generally provided for driving large quantities of air, under pressure, through the rotating machinery in well enclosed metal ducts. This forced air supply has a tendency to rapidly spread the conflagration in case of a small internal fire, and the air motor should be shut down automatically at the same time that the balanced type relay opens the electrical circuits. A modification of this plan has been suggested, to automatically set damper gates in such a way that the blower continues running, by circulating the same air, that is rapidly losing its oxygen content, through the



1. The test transformer and platform erected for applying the extinguisher liquid. (See page 142.)

machinery without permitting any fresh supply to enter the casing. The plan, to the writer's knowledge, has so far not had any trial in actual practice.

4. Power Transformers

Transformer fires in generating stations or substations which handle large capacities, are now a rather rare occurrence. About ten years ago, at the time when a number of hydroelectric and steam systems were being developed to large capacities, transformer fires were more frequently heard of, but since that time the writer believes the number of fires has materially decreased, while the number of transformer installations has greatly multiplied. Although there are no comprehensive data available

to prove the correctness of this assertion, from statistics collected individually from each of the large central station systems in this country, the writer feels justified in making this statement, which is based on the specific experience of one of the large hydro-steam systems in the east, on the writer's personal acquaintance with operating results obtained by numerous large power systems in different sections of the country and on communications transmitted from time to time on this subject to the engineering and operating associations represented in the central station industry.

Referring to the specific experience of one hydro-steam system in the east, there was during the first two years of operations (1911 and 1912) a total of nine transformer breakdowns on a combined powerhouse and substation installation of ten transformers of approximately 10,000 K. W. rating each. During the following nine years there were only three transformer breakdowns, although the average number of transformers in service during that period had been increased to sixteen, and the total connected capacity had more than doubled during that time.

The most plausible explanation for the reduction of transformer breakdowns (with or without fire) on the same system during the past ten year period, lies in the fact that the manufacturers have introduced improvements in the mechanical and electrical design of transformers, that better methods of protection of electrical apparatus against lightning disturbances and other over-voltages, have been installed and that the various accessories, such as cooling equipment, temperature indicators, means of preventing condensation, relays, etc., have been perfected.

Although transformer fires are rare, nevertheless if they do occur they can seriously cripple the whole plant and produce some of the worst shut-downs that central stations have on record. This is not due to the damage in the transformer itself but to the secondary effect produced by the escaping oil that may spread the fire to other parts of the equipment or to the whole station, and further due to the emission of dense smoke and gases that may disable the operating attendants and interfere with the quick electrical isolation of the damaged apparatus and restoration of service.

The immediate cause of transformer fires is believed to be the ignition of an explosive gas mixture in the space above the oil level (and not the power arc submerged in oil). After the cover is blown off and there is free exposure to air, it is quite possible that some small particles of burning insulation, hot metal parts, burning oil spray, or greatly superheated oil vapors, may keep up the oil fire on the surface of the tank. If the tank bursts open, discharging large quantities of oil, these same hot or burning particles may further ignite the spilled oil on the floors and give rise to a destructive blaze, involving the whole building.

The question has been raised frequently whether an oil submerged power arc, lasting only a few seconds or perhaps a fraction of one second, will cause extremely high local heating of a small volume of oil immediately surrounding the arc or whether it will produce a proportionately lesser temperature increase in a larger volume of oil. Subsequent to the experiments on transformer fires, which are described in detail later, a number of tests were made on the short circuit rupturing capacity of various types of oil circuit breakers, the well known function of which

is to quench the oil submerged power arc during the first few inches of the opening stroke. It was found by measurement on a number of these short circuit tests that the oil contents of the switch, less than two gallons per pot, had heated up only a few degrees, but small and greatly over-heated particles of oil and vapor thrown out with the movement of the switch rod, could easily spread fires when hitting combustible materials in the vicinity. It can be calculated that the electrical energy of 1000 K. W. applied for one second to one gallon of the average transformer or switch oil, will raise its temperature by about 180° C. (324° F.). In a central station system of say 150,000 K. W. rating, about equally divided between modern steam turbines and hydroelectric generators, interconnected through high tension transmission circuits, the initial short circuit current assuming a fault on the 13,000 volt distribution bus, i. e. on the low tension side of step-down transformers, will be about six times and the sustained current about one and a half times the total rated generator capacity of the system. Assuming a potential drop of only two percent across the arc, the initial energy put into the short, nearly all of which will be converted into heat effect, will be at the rate of heating up one gallon of oil over 3000° C. (5400° F.) per second and the heating effect of the sustained short will be at the rate of nearly 1000° C. (1800° F.) per second.

There has been some doubt whether the high voltage power arc alone, which is generally submerged in oil in case of an internal transformer breakdown, would be sufficient to set the oil itself on fire. Special tests were arranged by the writer for that purpose by connecting a 10,000 K. W. generator to a submerged arcing short in the casing of a 10,000 K.W. transformer, about nine inches below the oil level, and although the oil had been previously heated considerably above the normal operating temperature, in none of the tests was it possible to maintain the arc for more than a few seconds as the arc was extinguished by the oil itself. This phase of the experiment is described in section C-VII of the test report following. (See page 147.)

It used to be the practice to rely on quick-opening drain valves of large dimension for a speedy draining of the oil from a transformer when it emitted smoke at the top, and in some stations this practice is still being adhered to. This method, in the writer's opinion, provides a sure way of burning up all of the transformer windings and rendering the putting out of the fire still more difficult. Ample sized recesses and enclosed drains should be arranged for below and around the tanks of transformers and other apparatus that contain insulating oil if the tanks are liable to burst open in event of internal electrical breakdowns. This will reduce the fire hazard from the spreading of the spilled oil over large surfaces where there is free access of air, or over floor levels below where the fire might involve control equipment and other station apparatus.

Tanks of large power transformers in central stations should be designed to withstand moderate internal pressures, differing in this respect from the bulk of standard distribution transformers or from certain outdoor type of large self-cooling power transformers, so that in case of an internal explosion the cover plates would break or blow off before the side walls would rip open. Modern high-voltage transformers can

be obtained now that avoid entirely the air chamber inside of the casing. The bushings are fitted in oil-tight and a small tank located slightly above the transformer top and connected to the oil space inside of the transformer provides sufficient volume to take up the variation of oil level due to temperature differences. This arrangement not only avoids the formation of an explosive gas mixture above the oil level inside the transformer tank, but it is also helpful in eliminating the danger from condensed moisture in the air space.

Based on the transformer fire test described later in greater detail, there are two schemes recommended for putting out transformer fires, which will be found applicable in most of the existing installations. One plan recommended is to install on the roof of the building a gravity storage tank, containing about fifty gallons of carbon tetrachloride, and connect same through adequate piping to all large transformers in the station. The piping should not enter through the cover plates — which are liable to be blown off, but through the side walls of the tank slightly above the oil level. The perforated pipe line inside of the tank, similar to the test arrangement described in the report, should be rigidly fastened to the side walls so as to produce a spray and vapor effect immediately above the oil level. It is desirable to provide a master control valve, located conveniently in the station, that admits the extinguishing fluid into the main header, and individual valves to each transformer, located outside of the transformer compartment and accessible in emergencies. Although the admission of the extinguishing fluid to the transformer tank could be made automatic by providing a fuse plug, a check valve or a low pressure diaphragm in the pipe connection, this scheme is not as reliable because the amount and location of the internal pressure or temperature is uncertain.

Another scheme recommended for transformer fires will be found particularly applicable to such installations where there is a fireproof operating floor immediately above the transformer compartments. This plan is considerably cheaper in first cost and maintenance than the first scheme and requires only two standard size soda-acid extinguishers, piped up at opposite ends of the transformer tank. It has been found equally effective during the experiments on the 10,000 K. W. transformer as the carbon tetrachloride arrangement.

5. Oil Switch Fires

Relatively, the most frequent cause of fires in electrical stations handling large capacities are oil switch failures. Although the quantity of oil involved is very small, the disturbing effect of oil switch fires on service may be as bad as that of transformer fires, where the amount of oil is several hundred to one thousand times greater per unit. About ten years ago failures of oil switches were rather rare, while in recent years oil switch failures and station fires resulting therefrom have become more frequent occurrences. This condition has brought the operating companies and manufacturers to the realization that the identical type of oil switch, which ten years ago performed successfully all switching duties in the stations, has now shown up inadequate on account of the larger generating capacity and consequently increased short circuits that flow through the switch, and which the switch is now unable to open. Without wishing to go, at this time, into remedies that are possible to reduce the

rupturing task of switches on existing installations by the insertion of current limiting reactors, lengthening of time elements on relays, demagnetization of generator field, etc., or by modification of the design and adjustment of existing types of switches, the best prevention of oil switch fires naturally is to provide oil switches of sufficient capacity to rupture the worst possible combination of voltage, current, and power factor on any given point of the system, with a sufficient margin of safety to allow for slight imperfections in the adjustment of the switch mechanism, contacts, oil level, etc.

The formulation of a uniform duty cycle of a circuit breaker, and the establishing of a definite voltage and current limit for each type of switch which it is able to rupture, under short circuit conditions, by actual tie-in to large generating capacities, is now the subject of earnest study and experimentation, conducted by the national organizations of central station engineers and by individual operating companies and manufacturers. So far, however, it is apparent that the complete replacement of inadequate switches by a modern type of breaker, of a rupturing capacity sufficient to prevent failure under highest possible stresses, involves a considerable expense on large systems that have undergone a rapid growth of connected capacity in recent years. Such a rehabilitation of switching equipment calls not only for replacement of circuit breakers themselves, and their mechanisms, but also rearrangement of bus structures, switch cells, and of whole station layouts. Economic considerations therefore will stand in the way in many instances of carrying out these improvements at once. During the period of transition, all operating companies will be confronted with the problem of providing the best feasible compromise and must be prepared to minimize the disturbing effect on the service whenever oil switch fires do occur in the stations.

Methods of Handling Oil Switch Fires.

To reduce the disturbing effect of oil switch fires to service to a minimum, and at the same time limit the material damage to equipment, requires a certain systematic procedure with which the station men should be thoroughly familiar so as to cope promptly with the emergency, should it arise. The sequence of steps to be taken and the method of carrying out each step will differ somewhat with local conditions. The general plan recommended below is based on the writer's experience with specific occurrences and on the extensive tests conducted subsequently on the best methods of handling oil switch fires, which are described in greater detail in the attached reports.

(a) Electrical isolation and removal of voltage from the switch itself and from the bus sections and feeder compartments in the immediate vicinity affected by the fire, should be arranged partly by automatic switching, partly by manual operation. This step should be taken immediately, as with the spreading heat and gases the control wiring may become defective, and the electrical clearing by distant control from the benchboard may not be possible except during the first few seconds immediately following the breakdown. The operator should preferably err on the safe side by cutting out rather more than less sections of the station, as the spreading of the trouble later on to parts of the equipment that are still alive may throw additional short circuits on the rest of the system and give rise to new fires and endanger the life of the men working nearby.

(b) Where the type of oil switch makes it permissible, steps should be taken to prevent the falling over of switch pots and the spilling of burning oil on the floor. The fire in the switch pots themselves should be extinguished with a small amount of carbon tetrachloride. If the spreading of oil can not be prevented because the tanks have already ripped open, or have broken through openings into lower floors, the station attendants should use sand or bring into play some of the larger size soda-acid extinguishers to blanket the burning oil.

(c) Simultaneously with the previous step, or in case only a limited number of station attendants are available — as soon thereafter as possible, all windows and ventilators in the roof should be opened that would draw away the smoke from the oil fire. Particular care should be taken to keep the switchboard room free enough from smoke so that the operator can continue to read the instruments and be able to remain on his post.

(d) If the fire does not appear to be under control after a few minutes an emergency call should be sent out summoning assistance from the trouble crew or from other stations nearby, and from the local fire department, that can be helpful in putting out the fire with chemical apparatus (not water).

The above procedure to meet the emergency of an oil switch fire in a large station cannot be carried out unless adequate fire fighting apparatus is provided in the station and the crew is trained to act promptly and efficiently in the proper use of the apparatus. For training purposes, a more or less permanent set-up of high and low tension switch pots with cell structures will be found very helpful, where the operating attendants can be instructed by practical demonstrations in the extinguishing of fires, use of gas mask, etc.

Aside from the type of switch proper, the mounting and the immediate surroundings at the oil switch have much to do with the practice that should be adapted in each station for the putting out of oil switch fires. There will be a certain difference in putting out a low tension and high tension oil switch fire, although the switches themselves may be of a similar type. A peculiar feature of that type of switch for which a sample of detailed instruction is given below is that the switch pot is exceedingly strong, being made of seamless drawn steel, and that the pot, to the writer's knowledge, has never opened on the sides except for the small holes burned by the short circuits arc above the oil level. The oil can therefore escape only at the top, where the cover is apt to be blown off if the switch fails to function properly under short circuit conditions. It is not recommended that identical treatment should be adopted for other types of switches, or in cases where the surroundings differ materially from those to which these instructions apply, in regard to the fire hazard of adjoining equipment, accessibility to the oil switch compartments, location of switchboard gallery, ventilation in station, relation to other floor levels, etc.

As pointed out previously, damage to property will be found relatively small in case of oil switch fires in a modern station building, where an effort has been made to isolate the high and low tension compartments, segregate the bus structures and to employ, wherever possible, fireproof construction, etc. Aside from safety to life, quick restoration of service from duplicate buses and switches, and localization of electrical disturb-

ance are of a paramount importance, outweighing somewhat considerations of damage to property. In this respect, perhaps the method of putting out an oil switch fire in an important electrical station will differ from the purely "underwriters" point of view of putting out a fire with a minimum loss of life and property.

The delay in restoring service in most cases of oil switch fires, will be found to be principally due to the smoke in the station and insufficient ventilation, particularly around the control board. The Tisot type of army gas mask has recently been developed for particular use against oil fires, where the contents of carbon monoxide is higher than usually found in mines or chemical plants. Natural ventilation in the station buildings should be improved, and if possible mechanical draft should be provided in switchboard enclosures that permits drawing in of fresh air while at the same time driving out the gases from the oil fire that may penetrate from other parts of the building.

Sample of Operating Order, Dealing With Oil Switch Fires.

Low Tension Oil Switch:

1st. Clear the switch affected by opening its disconnectors and by any other switching which may be necessary. This will prevent the formation of an arc. If an arc has already formed it must be cleared by master field switch operation, splitting the station or by otherwise isolating the bus which is feeding the arc. Do not clear the whole station unless all other means fail.

2nd. Extinguish burning oil on the floor by means of sand.

3rd. If the doors of the switch cell have not already been blown off, knock them off with a switch hook.

4th. Extinguish the fire around the pots by means of sand. Be careful that no sand gets into the pots as this will make the fire worse.

5th. Extinguish the fire in the pots by a small amount of carbon tetrachloride; not more than one or two squirts should be needed.

6th. Let the fire on the walls of the cell burn itself out.

High Tension Oil Switch:

1st. Clear all buses within reach of a stream of water into the burning switch cell. Do not clear the whole station.

2nd. Clear the switch affected by opening its disconnectors and by any other switching which may be necessary.

3rd. Throw off the door of the switch cell if it has not been blown off.

4th. Extinguish the fire in the cell by use of soda extinguisher. Start at the bottom of the frame working up the legs, around the pots, above the pots, in the pots and finally the walls and roof of the cell.

6. Auxiliary Apparatus Containing Oil.

Among the many auxiliary apparatus that may give rise to station fires, there should be mentioned lightning arresters, oil cooled regulators, potential transformers, oil submerged choke coils, series transformers, etc. The original cause may be furnished by weakened insulation, voltage surges, lightning, deterioration of electrolyte in the arresters, etc., most of which can be detected in time by a systematic plan of routine inspection, such as testing the coil, careful observation of spark when charging arresters, measuring insulation resistance, etc.

Despite all precautions, breakdowns of this character will continue to occur, and dependent on location, supporting structure, surroundings, etc., similar methods for putting out the fire should be resorted to, as described under the heading "Oil Switch Fires."

Wherever practicable, all oil filled auxiliary apparatus should be located in such a way that the escaping oil, in case of explosion of the container, will not involve other high tension apparatus nearby, and that

2. Another view of the test transformer. (See also photograph No. 1.)

the bulk of escaping oil should be caught in recesses at the base of the apparatus, and carried off in ample sized closed drains to a cesspool, or into a drainage system outside of the station.

In General.

Soda-acid extinguishers cannot be used on live apparatus because the stream is conducting. Carbon tetrachloride can be used on live apparatus even at 70,000 volts because carbon tetrachloride is as good an insulator as "transil" oil (General Electric Company transformer oil). In fact, in some places carbon tetrachloride has been used instead of transil oil in oil switches. Carbon tetrachloride is dangerous, because when used on a hot fire it liberates free chlorine gas which forms a corrosive acid in the passages of the nose, mouth, throat and lungs and produces a choking effect. The presence of chlorine in the air can be detected by this sharp choking effect whereas the other gases likely to be present during a fire do not interfere with breathing so severely. The army gas masks offer protection against chlorine gas.

Carbon tetrachloride should be used very sparingly and should never be used in a closed space. It is for this reason that the fire on the walls of the low tension oil switches is to be permitted to burn out in preference to attempting to put it out with carbon tetrachloride. Such a large quantity of tetrachloride would be needed to put it out that the station would soon be filled with gas whereas the burning oil and paint on the walls will not cause as much trouble.

As soon as possible after a fire has occurred send someone to open

all windows that may assist in clearing the station of smoke. Inside switchboard room windows and doors should be closed. Roof ventilator blowers should be started pumping air inwards.

An oil switch fire may look worse than it is. After such a fire has once started there often is not a great deal of damage that can be done and the operator may take his time about putting it out. If there is any important telephoning or switching to do, this may be attended to first. Putting out an oil switch fire is ordinarily a one man job and only one man need be sent to put out the fire. The time of the two other men will be needed operating the station and attending to ventilation.

Type of Fire Fighting Apparatus for Large Central Stations.

The standard portable carbon tetrachloride extinguisher, even if more than one is used simultaneously, is not effective against a really hot fire. A further limitation is set by the frequently unavoidable condition around switch compartments where only one man can work effectively at a safe distance. A well aimed continuous stream from one apparatus is more effective than intermittent working with several apparatus. If the nature of the fire is such that the extinguishing fluid has a chance to produce a blanketing effect (for instance where the edges protrude a few inches above the level of the burning oil) and where the attendant can come very close to the burning object, there may be an opportunity to do effective work with only one standard extinguisher. Likewise, small surface fires produced by light oil spray or sparks on insulating material or wooden objects some distance away from the center of the heat, may be put out by the small streams of extinguishing fluid that are directed at the small areas more or less intermittently.

Taking as a typical example of a hot fire in a high tension station, the wood encased pot of a 70,000 volt H-3 oil switch (G. E. manufacture), about 10 inches diameter and 30 inches high, the small stream of carbon tetrachloride will extinguish the fire around a small area where it is applied, but a few seconds later when directing the stream to other parts of the pot the fire will re-establish itself in the area previously worked on. On fires of this sort the quenching effect is primarily needed, which is lacking in the small streams of carbon tetrachloride, but available in the soda-acid extinguisher or Foamite application.

During preliminary tests, conducted several years ago, it was found that the standard one quart container is quickly exhausted on an exposed hot fire involving only moderate areas, and for this reason one of the manufacturers was induced to develop at first a three gallon and later a one gallon container that throws a larger stream and works by air pressure that is pumped up by a small air pump and permits a better directing of the stream than other types of containers where the man must keep on pumping while at the same time aiming the liquid at the burning object. Many central station companies will find it to advantage to replace the large number of small one quart containers by a smaller number of larger size extinguishers. Small containers will still have their place back of switchboard panels and in other restricted locations where the fire hazards consist chiefly of wiring and small insulation exposed only to accidental low voltage arcs, and where the discharge of larger quantities of carbon tetrachloride is dangerous to the crew on account of the formation of poisonous gases.

It should not be assumed that mechanically a larger size extinguisher will be any more perfect than the standard one quart units. The openings get easily clogged up, the valves may get out of order and leaks will sometimes develop at the pump. They, as well as the standard one quart extinguishers, require frequent attention to insure proper functioning at all times. The apparatus should be gone over regularly once a month, in addition to the complete annual inspection, when weights should be checked accurately and the mechanism thoroughly overhauled.

In addition to the various small hand-carried extinguishers (carbon tetrachloride and soda or foamite) and to numerous sand pails, there should be in each station a larger size chemical fire engine of about forty gallons capacity, mounted on wheels in such a way that the carriage will pass easily through the clearances between walls and switch cell structures or other restricted passages. This engine should be used in case of major station fires that cannot be put out by the small extinguishers.

Precautions Against Station Fires Recommended in Design of New Plants.

A great deal of preventive fire protection work can be incorporated in the structural and electrical design when laying out a new power house or substation intended to handle large capacities and high voltage. Except for the oil contained in transformer, switches, etc., and for the necessary solid insulating materials of combustible character, very few combustible materials need be used with modern electrical equipment. If wood must be employed occasionally for switch rods, cell frames, handles, etc., it should be treated with fire retarding paints that will not impair its insulating qualities where needed. Asbestos lumber and other non-combustible material should be used wherever possible on compartment doors, partitions, etc., where the former practice was to use wood. Window frames and doors should be made of fireproof materials as recommended by the Underwriters' standards.

High voltage switches, transformers, lightning arresters and other apparatus that may start fires from electrical causes, should preferably be placed out-doors, which plan had been adopted recently in many instances, not only for the reason of reducing fire hazard but also for economy in the housing structures. Bus structures, feeder compartments and switch cells, whenever provided in duplicate, should be separated as far as possible so that trouble on one set of equipment will not spread over to the spare equipment. The electrical connections should be arranged in such a way that the station can be sectionalized easily by distant control from the benchboard, by means of tie and section switches. Likewise the control wiring and power supply from the control battery should be sectionalized so that in case of the spreading of electrical trouble or fire from the high tension equipment into the control wiring, the oil switches and other mechanisms are not rendered inoperative in the whole station. The battery itself should be located in a particularly well protected part of the building. Wherever possible, generators, transformers, regulators, and similar apparatus should be equipped for instantaneous automatic operation in case of internal breakdown. Connections to auxiliary apparatus such as station transformers, arresters, potential transformers, etc., should have ample cross-section and should have current limiting resistances in series, in order to reduce the current that would

flow through them in case of short circuits to a value that would not fuse or vaporize the conductor.

There should be ample ventilation through windows and large openings in the roof. Wherever practicable an attempt should be made to divide stations having a large floor area or several operating floors, in such a way that automatic or hand released trap doors will isolate from the rest of the structure that part of the building where an oil fire is liable to start. Each part, thus isolated, should retain ventilating facilities of its own.

The benchboard should be located at a safe distance from electrical apparatus that are subject to breakdowns, and an enclosure should be provided as a protection against smoke as well as against heat and cold. For safety to life and for the psychological effect of assurance to the operating crew, an emergency fire escape to the outside of the building should be arranged. The ventilation in the benchboard room and in the roof should be aided by motor driven fans. As in winter time frequently all windows are closed, the opening of many windows for the purpose of clearing out smoke will be quite a time consuming procedure, and all windows or at least a part of them should be equipped for motor operation controlled from the benchboard.

The foregoing remarks will make it obvious that a first class electrical and structural design, using adequate factors of safety on all apparatus, will remove the greatest number of fire hazards, that now exist in many large central stations, which have been gradually developed to their present size from small beginnings, years ago. Nearly everything that designers specify for the purpose of good and safe operation and maintenance will indirectly work for a reduction of fire hazards in the central station industry.

Extinguishing Transformer and Oil Switch Fires.*

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*Tests made and reported on under the author's direction by A. F. Bang, Testing Engineer, and C. T. Sinclair, Assistant Testing Engineer of the Pennsylvania Water and Power Company.

A. Introduction.

The oil used in transformers serves the twofold function of insulating and cooling. To properly perform its function of insulating it is necessary that the oil have a high dielectric strength; to properly perform its function of cooling it should not be too viscous. In addition to these qualities it should have a high flash point. Speaking generally, a low flash point usually accompanies low viscosity, which explains why many transformer oils have a fairly low flash point. This low flash point naturally means increased fire risk. However, transformer fires are a rarity; but when one is once started it is dangerous and is often extinguished only after considerable damage has been done, and then with difficulty. The following data on the flash points of oils used on the Pennsylvania Water and Power Company system was obtained from tests made at Holtwood.

Flash and Burning Points of Oils Used by Penna. Water & Power Co.

Make	*Name*	*Used*	*Flash °C.*	*Burn °C.*	*From*
G. E.	No. 6	Curr. Trans. & Oil Sw.	150	171	Holtwood
G. E.	No. 8	Trans.	134	148	Holtwood
West.	High Flash	Trans.	178	195	Highlandtown
West.	Lectroseal	Trans. B. E. A.	136	148	B. E. A. Furnace Plant
West.		Trans.	162	185	Holtwood

It will be noted that none of these oils have a very high flash point.

In consideration of these facts it was decided to make a number of tests to determine the most desirable method of procedure in extinguishing a fire in a transformer should one occur.

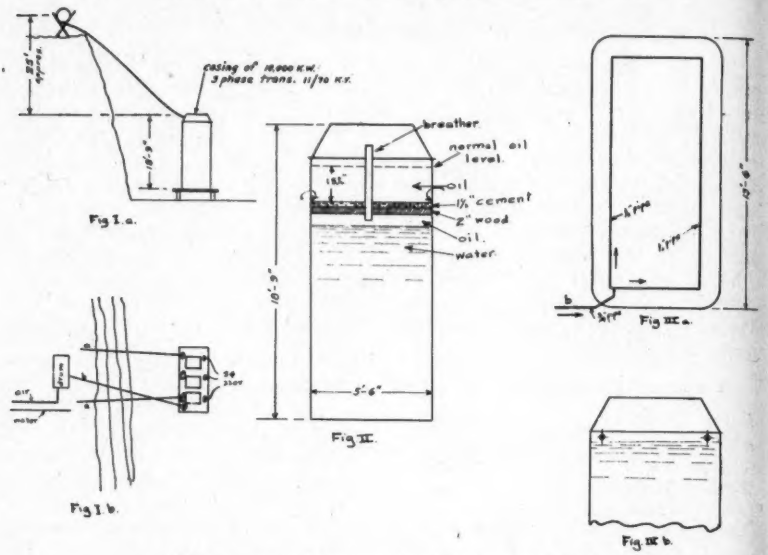
In addition to the transformer investigation similar tests were planned for oil switch fires both low tension and high tension, as difficulty has been experienced in the past in extinguishing these fires. And there is always the possibility of a fire starting when oil switches open under overload for the heat then developed is usually more than equal to that required to raise the small quantity of oil above the flash point. There is in each pot, both high and low tension, about two gallons of oil.

For the transformer tests four general methods were considered:

1. Carbon tetrachloride. Sold under the trade name of Pyrene, J. M. Fire Extinguisher Fluid, Castle Liquid, etc.
2. Bicarbonate of Soda and Sulphuric Acid. Referred to as "Soda," in this report. A carbon dioxide and water extinguisher.
3. Water.
4. Foamite, a form of carbon dioxide extinguisher.

For the oil switch tests five general methods were considered:

1. Carbon tetrachloride.
2. Sand.
3. Damp Sawdust.
4. Bicarbonate of soda and sulphuric acid.
5. Foamite.



Arrangement and construction of the test transformer.

B. Method for Transformer Fire Tests.

It was desirable to make the tests with conditions approximating those found in normal operation. A spare transformer shell, which was available for test purposes, was moved down along the east shore of the tail race just beyond the old mixer plant. This location was chosen as the fire would be clear of all buildings and also of the transmission line; and much of the auxiliary apparatus could be located on the embankment overlooking the transformer location, which made a desirable point of observation (See Fig. I and photograph 2). Compressed air and water lines were run to this elevated point, and a drum was mounted to contain some of the fire extinguisher fluids. (See photograph 3.) Two three-quarter inch pipes *aa* Figure I, were provided which ran to opposite ends of the transformer. A third three-quarter inch pipe *b* was installed which connected the drum to the spray pipe in the transformer (described below).

A wooden platform was built in the transformer two inches thick (See Fig. II), which was covered with a 1½ inch layer of cement. (Supports for wooden platform not shown.) The space below this platform was filled with water within one or two inches of the under side. General Electric Company "Transil" oil (flash point 134° C., No. 8 oil) was then poured in until the normal oil level was reached, which of course filled up the space between the water surface and the under side of the platform. The depth of the oil was about 15½ inches (above the top of the platform) — or about 650 gallons.

The platform acts as a heat insulator separating the oil above the platform from the oil and water below the platform; and also as a support for the electric heaters described below. The fact that the platform did act as a heat insulator is proven by the following: The oil in the trans-

former was heated to about 200° C. (390° F.); when the hand was placed on the outside of the shell that was in contact with the oil it was found to be hot. On moving the hand down past the level of the platform, the shell was found to be cold, there being a sharp line of demarkation.

It is interesting to note at this point that after all of the tests were completed the flash point of the oil was measured and it was found that it was 145° C. as compared with 134° C. before burning. The burning point was 159° C. as compared with 148° C. before burning.

As the platform does not make a liquid tight joint at its junction with the transformer shell, the liquid below the platform can pass up into the liquid above the platform, and vice versa, thus allowing for expansion and contraction of the liquid. (See curved arrows Fig. II.) While the breather pipe (Fig. II) also takes care of this to a certain extent, it was primarily installed for filling purposes. As stated in the preceding paragraph there is a layer of oil *under* as well as *above* the platform. When the liquid below the platform expands oil and not water will be forced above the platform through the cracks; this prevents short circuiting of the electric heaters resting on the platform, and other complications such as the formation of steam.

Neutral ground resistances were used for heating. Three units of two boxes each in parallel were connected delta to the 220 volt station transformer, the power consumption being about 80 kilowatts. Calculation showed that these grids should heat the oil to 10° Centigrade above the flash point in about two and one-half hours, which was approximately the time required in practice. These grids were placed on the platform and connected before the shell was filled with oil. Leads were run out through the three low tension bushings which were still in place.

A messenger wire was stretched from the hill to the transformer and a small car attached to same in such a manner that when the car was released at the top of the hill, the action of gravity carried it down to the transformer on the messenger wire. A second wire, attached to the car itself, was used to pull the car back. When the oil had reached the burning point a piece of waste saturated in gasoline was attached to the car, and ignited. The car was then released, and the burning waste was carried down to the top of transformer where the oil vapor was ignited. This method of ignition proved very successful.

In applying carbon tetrachloride it is essential that a jet of the liquid impinge with considerable velocity on a solid surface in order that a vapor may be formed which in turn blankets the fire and extinguishes the same by cutting off the supply of air. (Spraying the liquid directly on the fire is usually ineffective.) A one half inch pipe was installed in the transformer extending around the inside of the shell (See Fig. III) making a complete loop just above the oil surface. Holes were drilled eight inches apart with a 3/32 inch drill and the pipes placed so that the spray was directed slightly upward. The jets cross and impinge on the opposite side of the transformer casing. A 3/32 inch hole was decided on after testing a number of perforations of different sizes and shapes. A 3/4 inch pipe connected the drum (Pipe *b*, Fig. 1) to the ½ inch spray pipe, the liquid passing through the spray pipe in both directions as shown by the arrows (Fig. III). In this 3/4 inch pipe, just before it entered the transformer, a valve was located which was operated from the em-

bankment overlooking the transformer. The object in locating the valve at this point was to reduce the time taken for the liquid to reach the flames, and also to reduce the amount of air forced in on the flames.

Calculations showed that if a tank of carbon tetrachloride were placed on the generator room roof the pressure at the transformer would be slightly less than 50 pounds per square inch. As no such static head was available for test purposes compressed air was used to bring the pressure at the spray pipe to 50 pounds.

In applying the bicarbonate of soda the two pipes *aa* (Fig. II) were used which lead directly to the oil surface.

The spray pipe (*b*), described above, was used for the water test as well as the carbon tetrachloride.

In applying the Foamite a scaffold was erected on the level of the transformer top about 15 feet distant, and the liquid applied directly (See Photograph 1).

Photographs 1 and 2 show the pipes leading to the transformer from the hill. The two nearest pipes in 2 are the ones used in applying the soda; and the third pipe (farthest away), showing the gauge and valve indistinctly, is the pipe from the drum used for carbon tetrachloride and water.

C. Tests With Transformer Fires.

I. Carbon Tetrachloride. (Tests No. I-V & XV).

The current was thrown on at 2:00 P. M. Nov. 13, 1919, and at 4:15 P. M. the temperature of the oil was approximately 165° C. (330° F.). The oil was then ignited. Of the three covers on the top of the transformer the two end ones were in place, while the middle one was off as in photograph 2, leaving an opening two feet square. After burning 5 minutes carbon tetrachloride was applied through the spray pipe at about 48 pounds pressure. The fire was extinguished in about 10 seconds with an appreciable amount of smoke and a slight increase in the volume of flame. In almost every test there was at least a temporary increase in the volume of smoke and flame at the time the liquid was applied. The oil was ignited two more times, but the temperature had dropped (due to the current being off during burning period) and the fire went out of its own accord. It was estimated that four gallons of carbon tetrachloride were used to extinguish the fire. For the next test it was decided to wait until the oil had reached a higher temperature so that the condition of the test would be more severe.

The following morning, when the temperature had reached 200° C. (392° F.), the oil was ignited. The ignition took place quite rapidly, and with considerable noise, and a heavy flame about six feet high shot out of the uncovered opening of the transformer. The flames were rather heavy and considerable smoke was emitted. After burning for 5 minutes carbon tetrachloride was applied, which extinguished the fire in 10 seconds. The flames and smoke were considerably increased when the liquid was applied, especially in the first moment of application. This fire was hotter than the previous fire. About 5 gallons of liquid were used.

Immediately after this test a similar test was made, except that the oil temperature was slightly higher (about 210° C). Note: Temperatures were measured by means of a graphic thermometer installed with its bulb near the upper surface of the oil. After burning 5 minutes carbon tetra-

3. Drum containing extinguishing fluids used in tests.

chloride was applied, which extinguished the fire in 10 seconds with about 6 gallons of liquid. The appearance of the fire and smoke was about the same as in the former test.

II. Bicarbonate of Soda and Sulphuric Acid. (Tests No. VI-VII and XVI.)

The next method tried was the "Soda" method, employing an ordinary 2½ gallon soda-acid extinguisher. These extinguishers will throw a stream approximately 25 ft., but they appear to be more effective if used closer to the fire. It was desired to know the volume of the carbon dioxide product generated in the extinguisher; and measurements showed that one of the 2½ gallon extinguishers generated about 25 gallons of the gas,

compared with 23 gallons as calculated. In other words, the tank will generate about 10 times its own volume of gas. Assuming that the area of the transformer is 75 sq. ft., one of the extinguishers should produce a layer of blanketing gas over one-half inch deep, and two extinguishers would, of course, produce a layer about one inch deep.

In using this method the two 3/4 inch pipes *aa* (Fig. I) were used, the nozzles of the extinguishers being inserted in the pipes. When the oil had reached 200° C. (392° F.) ignition was made; and at the end of five minutes two extinguishers (one at each pipe) were inverted. The fire was extinguished approximately 20 seconds after the extinguishers were inverted. Allowing 12 seconds for the liquid to run down the pipe, 8 seconds was the time required to extinguish the fire. About two gallons of the liquid was used. The fire was extinguished with less flame and smoke than in the case of carbon tetrachloride; however, there was an increase in the volume of smoke and flame when the liquid was applied.

This test was repeated with one extinguisher only. This required about 12 seconds actual time and about 1½ gallons of the liquid. A slight increase in the volume of the smoke and flame was observed.

A final soda test was made by removing all three lids, leaving the top of the transformer open. The fire produced was the most violent yet tried; great quantities of smoke and flame were emitted. A single soda extinguisher was applied at one end of the transformer through pipe *a*. At the end of 25 seconds most of the fire was extinguished, but the fire in the far end of the transformer hung on for 35 seconds more, making the total time 60 seconds for extinguishing the fire. The entire contents of the extinguisher was used.

III. Water. (Tests No. VIII-XI.)

With the oil burning at a temperature 210° C. (410° F.) water was applied through the spray pipe. About 10 gallons of water extinguished the fire in 28 seconds. When the water was applied a flame about 20 feet high shot out of the transformer with great quantities of smoke and steam. Oil was thrown out through some of the openings of the transformer. This test was repeated several times with the same results.

IV. Foamite.

Foamite is the trade name for the combination of sodium bicarbonate, water and licorice with aluminum sulphate. When the two liquids are mixed (by inverting the tank in a method similar to the soda extinguisher), the licorice forms a binder which holds the carbon dioxide generated in the form of a very light foam which has the property of adhering to most solids that it impinges upon. This cuts off the air supply and extinguishes the fire. Foamite floats on water or oil; however, it finally disappeared, in our case after a few hours, from the oil surface.

On Nov. 24th a representative of the Foamite Firefoam Co. demonstrated the apparatus and successfully extinguished the fire in the transformer by squirting the liquid directly on the oil surface. (See photograph 1.) The photograph shows the platform erected for applying the Foamite. Approximately one-half of the contents of the extinguisher was used. The fire was extinguished with little smoke and flame in 15 to 20 seconds.

V. Explosion. (Tests No. XIII.)

Information was desired as to the effect of igniting the oil with an

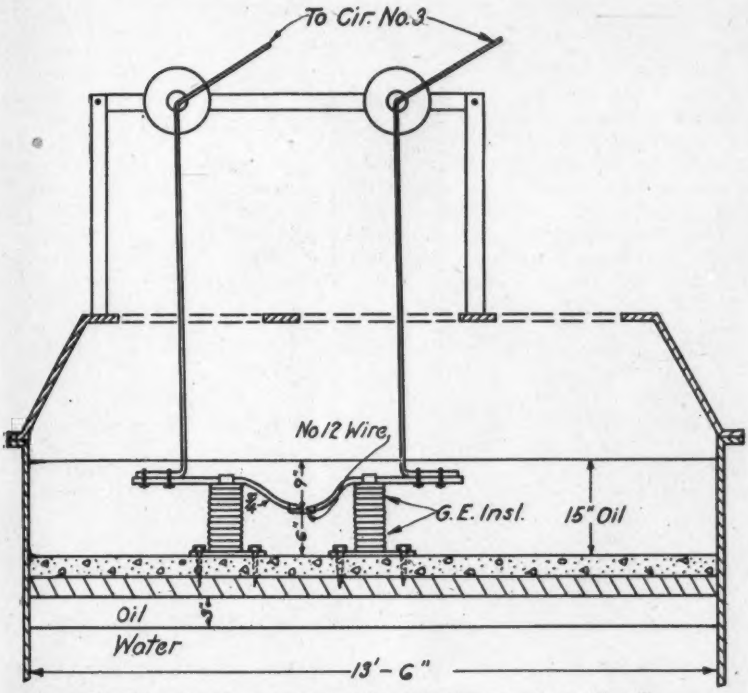


Fig. IV. Showing arrangement for producing power arc under oil.

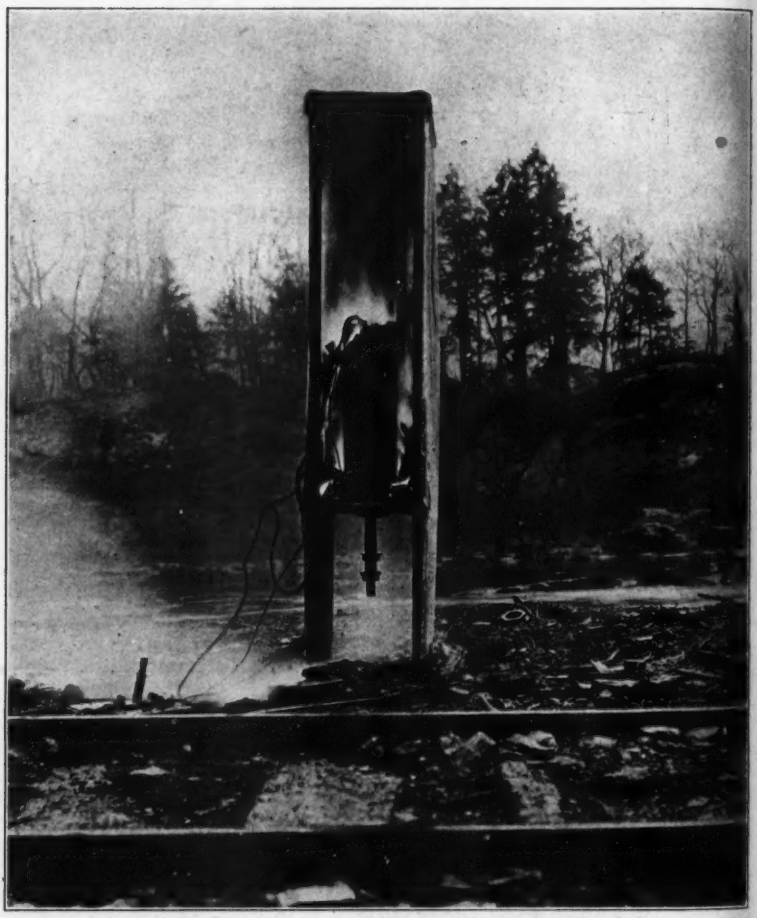
inflammable vapor in the transformer, with all covers in place. To accomplish this all openings were stopped up excepting a small opening in the top for ignition. The oil was brought to a temperature of 210° C. (410° F.) and ignited. The lids were raised several inches, one edge resting on the transformer top and the lid tending to rotate about this edge as on axis. The lids settled back in place. This test was repeated several times.

VI. Cutting Off Air Supply. (Test No. XII.)

On each of the above tests (explosion tests), the fire went out of its own accord, evidently through lack of air as the temperature of the oil was sufficient to keep the oil ignited. To confirm this, air was admitted through one of the pipes *aa* (Fig. I) under pressure, just as the fire was about to die out. The fire immediately brightened up and burned violently. This was repeated several times.

VII. Transformer Fire Tests with Submerged Power Arc. (Short Circuit Tests.)

The transformer shell previously used for the fire extinguisher tests was arranged for producing a power arc under oil (See Fig. IV) with the object of observing the action of the arc and comparing the fires



4. Arrangement for testing extinguishment of low tension oil switch fires.

produced by it, if any, with the fires produced by heating the oil gradually as in the previous tests.

"One of the 70,000 volt circuits (Circuit No. 3 from Holtwood to Lancaster, Pa.) was taken out of service and two cables run from the gap in the transformer to phases A & C on tower No. 134. Two jumpers connected these two phases at the power house to the 11,000 volt sleet bus. The procedure was then as follows: The auxiliary bus was separated from the main bus and tied in with the sleet bus. The short was thrown on by closing the generator switch (No. 6 generator, rated at 12,000 K. W., being used for the test) which fused some No. 12 copper wire shorted across the gap, and started the arc in the transformer shell.

The two outside phases were chosen for the test, as this reduced considerably the force action between the conductors, and there was some doubt as to the ability of the post type insulators on the sleet bus to stand up under the short.

TEST No. 1. The gap in the oil was 1 inch and shorted by a piece of No. 12 copper wire; the temperature of the oil was 65° C. (149° F.); the generator voltage was brought to 6000 volts by reducing the field as far as possible and then lowering the frequency. The generator switch was then closed causing the arc to start in the oil. At the end of 5 seconds the field switch was pulled. There was no indication in the power house that the short circuit had taken place and there was but a slight disturbance in the oil in the transformer.

TEST No. 2. All apparatus was grounded and preparations made for the next short. The gap was closed to ½ inch and two No. 12 copper wires placed across the gap. The short was thrown on at 8000 volts, and the field opened at the end of 8 seconds. From the noise of the machine in the power house, it appeared that the short lasted but a fraction of a second. A disturbance was again noted in the oil, slightly greater than in the first test.

Upon examining the gap, it was found that one of the insulators had broken off, which had to be replaced.

TEST No. 3. The gap was now reduced to 3/16 inch and the two No. 12 copper wires run through the gap as well as across it. The short was thrown on at 10,000 volts and the field opened after 8 seconds. The indication in the power house was that the short was of 2 seconds duration. Considerable disturbance in the oil was noted, and a quantity of smoke accompanied by flame was noted, which lasted for a fraction of a second. The flame and smoke was probably the result of the vaporized oil in the vicinity of the arc, which ignited. The main body of oil did not burn at all. When the two 3/4 inch brass rods (used for the gap) were examined it was found that about ½ inch of each was burned away.

TEST No. 4. The gap was now set at 1/16 inch or just about the thickness of the No. 12 wire which pressed through the gap. The short was thrown on at 10,000 volts and the field opened after 8 seconds. The short held on for about two seconds, producing considerable disturbance in the oil in the transformer. A flame was again noted accompanied by smoke, probably slightly smaller in quantity than in test No. 3.

SUMMARY OF TESTS. In none of the tests did the oil body ignite, but in the last two tests a quantity of smoke was produced and flame of short duration. As stated above, the flame was probably the result of the oil in the immediate vicinity of the arc vaporizing and igniting.

Test No.	*Time A.M.*	*Volts*	*Freq.*	*Field Amps.*	*Gap*	*Duration Sec.*	*Remarks*
1	11:08	6000	18	160	1"	Fract. Sec.	No indication of short in power house. Small splash in oil.
2	11:31	8000	22	180	½"	"	Machine in power house made some noise. Small splash in oil.
3	12:31	10000	24	215	3/16"	2	Machine groaned for 2 sec. Splash in oil, flame and smoke.
4	12:48	10000	24	220	1/16"	2	Machine groaned for 2 sec. Splash in oil, flame and smoke.

NOTE: In all tests two of the three covers were off.

5. Arrangement for testing extinguishment of high tension oil switch fires (after foam was applied).

D. Method For Oil Switch Fire Tests.

In this test as well as the transformer test operating conditions were simulated as far as possible. The two sizes of switches in general use at present are General Electric Type H-3 11 K. V. and 70 K. V. A single compartment (one phase) of each size was constructed of sheet iron mounted on a pipe frame (see photographs 4 and 5). The dimensions of the low tension compartment (11 K. V.) are 13½ inches by 27 inches by 57 inches; the dimensions of the high tension compartment (70 K. V.) are 45 inches by 68 inches by 87 inches. Oil pots were mounted in these compartments similarly to their mounting in an actual switch; however,

6. Applying sawdust to oil switch fire.

no insulators were used. The only effect that the absence of an insulator would have is that the opening in the top of the low tension pots is larger without the insulators; but in case of an actual oil switch fire it is probable that this top would have been blown off and the condition would be as in these tests.

Electric heaters were placed in each pot to bring the temperature of the oil well above the burning point. All woodwork used in the switches was duplicated in the test compartments, and saturated with oil.

E. Tests With Oil Switch Fires.

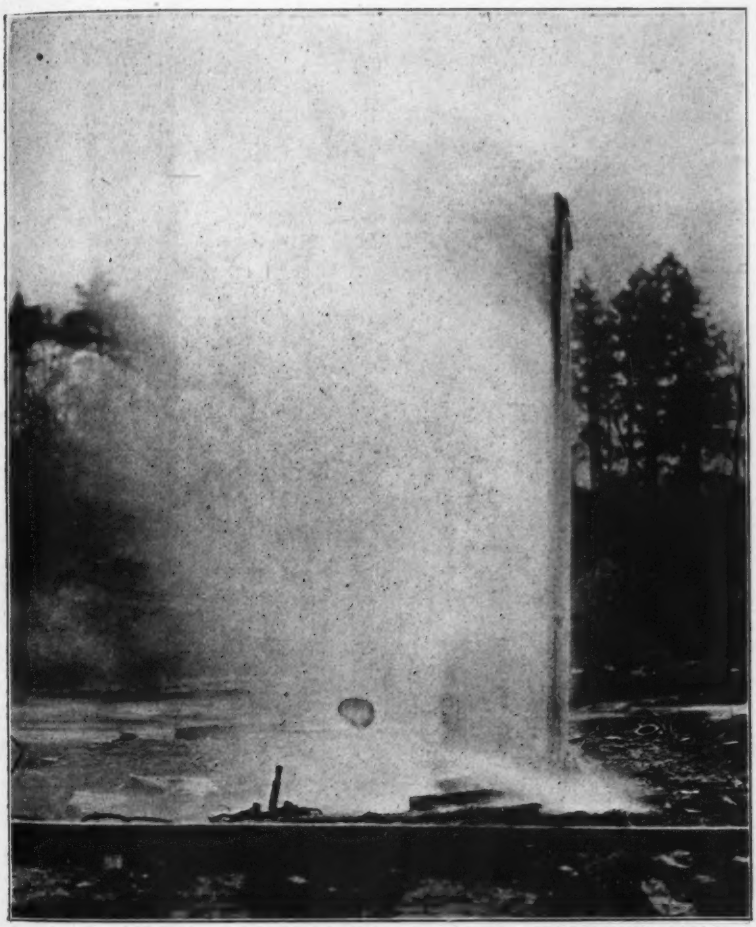
I. Low Tension Oil Switch (11 K. V. 800 amperes).

On Nov. 24th current was applied to the heaters in the low tension

switch and the oil temperature brought well above 200° C. (390° F.) (The quantity of oil was about 3½ gallons instead of 2 gallons in both high tension and low tension tests.) In addition to this a wood fire was built in the bottom of the compartment and quantities of oil thrown on, making a very hot fire. An attempt was made to extinguish this blaze by means of a one gallon pump type carbon tetrachloride extinguisher, but dirt clogged up the nozzle and the valve refused to seat. Foamite was then applied and the fire extinguished after the entire contents of the 2½ gallon extinguisher had been used. (Tests No. I-II in Summary.)

Several days later the tests were repeated on the low tension switch. The oil temperature was run up to about 265° C. (500° F.) and the tops of the pots only ignited. This, of course, made only a small fire, which was extinguished by the one gallon carbon tetrachloride extinguisher: (extinguisher had been repaired). A hot fire was then built in the bottom of the compartment of oil soaked wood, giving rather violent flames. Carbon tetrachloride was applied with no effect whatsoever. Two buckets of damp sawdust were thrown on, one in each side of the compartment. Photograph 4, is typical of this fire. However, the violence of the fire in this and other illustrations cannot be appreciated from the actual photograph, as flames apparently do not reproduce well photographically. After applying the sawdust the flames were reduced to a small blaze in the rear of the compartment behind the pots and a small blaze in each of the pots. Photograph 6 shows this condition fairly well, and also the method of applying the sawdust. An attempt was made to throw some sawdust over the tops of the pots to reach the fire in the rear, but a quantity of sawdust fell into the pots. This threw blazing oil over the top of the compartment causing a violent fire. Photograph 7 shows the result of this. The oil soon burned off the sides, and two more buckets of saw dust reduced the blaze in the bottom to a small fire. Carbon tetrachloride was then applied to the pots with good effect. (Tests No. III-V in Summary.)

The third series of tests was then made. A simple fire in pots only, was first extinguished by carbon tetrachloride. A fire was then built under the wooden door which set fire to the door and spread to the pots. This was a very slight fire and was quickly extinguished with carbon tetrachloride. The oil temperature in the front and rear pots in this test was 230° C. (446° F.) and 270° C. (518° F.) respectively. The temperature of the oil was then increased to 260° C. (500° F.) and 300° C. (572° F.) and the fire under the door started, as well as a fire in the compartment. Oil was thrown on and a very hot fire resulted. The door was removed, and oil was thrown over the fire and on the sides of the compartment causing a violent fire. A total of four buckets of sand were applied, which effectively reduced the fire to a small blaze in the pots which could easily have been extinguished with carbon tetrachloride. However, the pots were permitted to burn, and a quantity of sand thrown over the pots to the rear of the compartment (as in the test using sawdust). Some of the sand fell into the burning oil pots, and flaming oil was thrown over the sides of the compartment. Photographs 6 and 7 show the compartment before and after the sand was thrown into the pots. (NOTE: These photographs are used to illustrate the sawdust test also, for the results were the same in both tests.) The violent



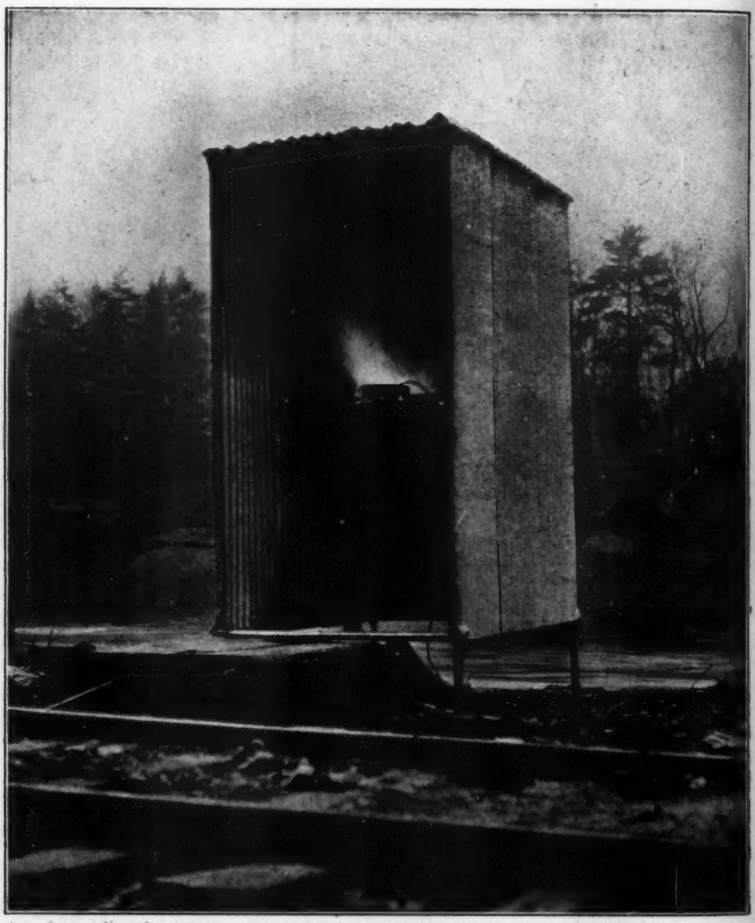
7. Fire temporarily intensified by allowing sand or sawdust to fall in the oil switch pot.

fire resulting was reduced by the application of more sand.

Later a fire was made in the low tension compartment and allowed to burn ten minutes. A soda-acid extinguisher was used and the fire extinguished in 20 seconds; the fire was thought to be out at the end of 8 seconds, but a short time later a small fire was found in the rear of the compartment, which was not extinguished until 20 seconds had expired. (Tests No. VI-X in Summary.)

II. High Tension Oil Switch (70 H. V. 300 amperes).

The tests on the high tension oil switch were made December 9. The oil was heated to a temperature of 240° C. (464° F.) and the pots ignited. A slight blaze resulted which was readily extinguished by carbon tetra-



8. High tension oil switch fire extinguished by carbon tetrachloride.

chloride. (See Photograph 8.) (Test No. I.)

A large fire was built of oil-soaked wood under the pots. Oil was thrown over all wood-work and the sides of the compartment, giving a very hot fire, similar to that shown in photograph 9. The temperature of the oil at the beginning of this test was well above 300° C. (575° F.). Foamite was applied and the fire extinguished in 15 seconds using less than one gallon of the liquid. (Test No. II.)

The compartment was then prepared for another fire similar to the above, but probably more violent. One-half of the contents of a soda extinguisher was required to extinguish this blaze in 20 seconds. (Test No. III.)

A fire was again started in the compartment which was permitted to burn for five minutes oil being thrown on constantly. Photograph 9 actually represents this case. At the end of this time it was decided that the fire had penetrated the woodwork to a reasonable depth, and soda was applied. The contents of one 2½ gallon extinguisher was required to extinguish the fire in 45 seconds. This was probably the most intense fire that had been started, and some little difficulty was experienced in extinguishing it. (Test No. IV.)

It is believed that had Foamite been used on this fire less difficulty would have been experienced in extinguishing it. Photograph 5 shows the compartment after Foamite had been applied. The Foamite can be seen on the woodwork.

III. Wood Fires.

Several wood fires were built with a view of determining the comparative effectiveness of the several extinguishers on open fires of this type. The summary at the end of this report indicates the tests as made. These fires were supplied with quantities of oil, and were very hot. The Foamite is extremely effective on fires of this type, for the thick foam from the extinguisher sticks to the wood and is very dependable in preventing re-ignition. The soda is also very effective, but it is not quite as rapid in its action as the Foamite. Some of the carbon dioxide gas which would otherwise be effective is carried away by the wind if the fire is in the open. Carbon tetrachloride has been applied to the open fires with no effect whatsoever; fumes were liberated which resembled chlorine gas in its effect on the throat, and it was impossible to stay near the fire when these fumes were being given off.

F. Conductance Tests For Fire Extinguisher Fluids.

While it was known that both soda and Foamite liquids are conductors, tests were made to determine whether or not the jet as it comes from the tank was a conductor. The apparatus was set up as shown in photograph 10 which shows the arrangement for putting the jet from a soda or Foamite extinguisher in series with the secondary of a potential transformer and spark gap. One terminal of the potential transformer secondary (about 11,000 volts) is connected to the spark gap, and the other side of the spark gap is connected to the nozzle of the extinguisher. The other secondary terminal is connected to a metallic target against which the jet is to impinge. This apparatus is placed on insulators as shown. With these connections the jet when started will complete the circuit of the transformer secondary with the exception of the small spark gap (telephone vacuum lightning arrester) which will spill over at about 200 volts A. C. In making these tests the extinguisher nozzle was fastened to the movable wooden platform as shown in the photograph so that the jet could be readily directed on the target.

Tests were made with about six soda extinguishers and one of Foamite, but in no case did the gap spill over. The length of the jet (from nozzle to target) varied from six to fifteen feet. However, when the spray from the jet had covered the insulator supporting the target, leakage occurred over the insulator (70 K. V. bus type) to ground (the other side of the secondary was grounded). From this it would appear that this length of *jet* is not a conductor, but the liquid is a conductor.

Arrangements were then made to put higher voltages on the jet by

means of the testing transformer. A jet six feet nine inches long successfully stood up against 80,000 volts. A jet of the same length gave a resistance reading of infinity, measured with the Megger instrument.

The target was then mounted on a switch stick so that the length of the jet could be altered at will. The jet showed a resistance reading of infinity up to about 44 inches from the nozzle, when it suddenly dropped to about 40 megohms. A slight further movement towards the nozzle dropped the resistance of the jet well below four megohms, the lowest reading of the instrument.

A 70 K. V. bus type insulator was sprayed with the soda liquid, and potential applied immediately. The voltage at which flashover first occurred was not readable on the testing transformer meter, but in all tests made it is believed to be below 2000 volts. Subsequent readings taken every minute indicated that the flashover voltage rose to above 140,000 volts in about five minutes.

This group of tests indicates conclusively that it is unsafe to use the soda extinguisher on live apparatus: first, because of the danger to the individual in getting too near the live apparatus with the jet; and, second, because of the danger from flashover.

G. Conclusions.*

I. Transformers.

The four methods under investigation for extinguishing transformer fires were: 1 Carbon tetrachloride, 2 Soda-acid, 3 Water, 4 Foamite.

The first method, CARBON TETRACHLORIDE, is very effective in extinguishing these fires if properly applied, about five gallons of liquid being required for the transformer under test. Should this method be adopted it would be necessary to install a loop of perforated pipe in each transformer with a storage tank (probably on generator room roof) and a rather extensive system of piping. This would necessitate frequent and careful inspection as well as comparatively high first cost. There is the additional disadvantage of the disagreeable fumes being liberated.

The third method, WATER, possesses the same primary disadvantage as carbon tetrachloride, i. e., extensive piping system. It has a more serious disadvantage of causing a great quantity of smoke and flame and likewise agitating the oil surface so violently that oil is thrown out of the transformer. In addition to this, a very slight leak in the valve might permit enough water to get into the oil to reduce its dielectric strength materially, for it is understood that the presence of only a very small percentage of moisture in oil may reduce its dielectric strength to half normal.

The fourth method, FOAMITE, is very effective, but it must be applied directly to the surface of the oil; or else mixing valves must be provided for each transformer with much additional piping (two pipes to each transformer) and two reservoirs.

The second method, SODA, may be said to be equal if not superior to any of the other methods as far as effectiveness is concerned. It is easier to apply than any of the other methods, only two short pipes being

* NOTE. Some of these conclusions obviously are intended to apply particularly to the plant of the Pennsylvania Water and Power Co. It is the thought of the author, however, that these conclusions may be helpfully applied to other stations, with such modification as may be needed to suit local conditions.—*Ed.*

9. A hot blaze caused by throwing oil on the fire.

needed leading from the low tension oil switch gallery through the transformer shell and emptying on the oil surface (one pipe at each end of the transformer). This equipment would be low in first cost and in maintenance. This will provide a rather flexible equipment, as a few of these extinguishers will furnish protection for all of the transformers, and in addition furnish protection for other fires. Where there are a number of these extinguishers at various places in a station they might be made to perform the double duty of protecting the transformers and fulfilling the Underwriters requirements. The use of the soda-acid extinguisher has also the minor advantage of cheapness in recharging. The cost of the recharging material for a 2½ gallon extinguisher at the present time is

approximately 11 cents.

Litmus tests were made to determine whether or not the soda extinguisher had acid, basic, or neutral properties, and the results of all tests seemed to indicate that the solution was neutral. A neutral solution should have no more effect on the windings of the transformer than water. As a matter of precaution it is thought that the oil should be removed as soon as possible after the extinguisher has been applied, and filtered in the usual manner.

In view of these facts it is recommended that the bicarbonate of soda and sulphuric acid fire extinguisher be used for protecting the transformers. There should be two three-quarter inch pipes leading to opposite ends of each transformer so that two of the standard extinguishers (2½ gallon) may be applied simultaneously. These pipes should lead preferably from the low tension oil switch gallery direct to the transformer, and the extinguisher located nearby.

II. Low Tension Oil Switches.

There were five methods of extinguishing oil switch fires under investigation: 1. Carbon tetrachloride, 2. Sand, 3. Damp sawdust, 4. Soda-acid, 5. Foamite.

The first method, CARBON TETRACHLORIDE, was tried on some of the hotter fires with no success whatsoever. The only fire that was successfully extinguished was a small blaze confined to the pots. This is, however, the only method where the equipment may be left alive.

SAND, the second method, was found to be fairly effective. It was not feasible to extinguish the entire fire (fire in pots) by sand; so the means employed was to reduce the fire as far as possible by throwing sand in the *bottom* of the oil switch compartment and then extinguish the remaining fire in the pots by means of carbon tetrachloride. This combined method was rather effective. The great danger in applying sand lies in the possibility of the sand being thrown directly into the oil pots, which causes a very violent fire. When sand is used precaution should be taken to throw the sand on the bottom of the compartment only, and to permit no sand to fall into the pots. Photographs 6 and 7 show the oil switch before and immediately after sand has been thrown into the pots.

DAMP SAWDUST was then tried, and its effect was very similar to that of sand. It probably has the advantage of spreading out more evenly over the bottom of the compartment and smothering a little more of the fire for a given quantity applied, but it has the slight disadvantage over sand that it must be kept damp. If applied, the same precautions should be taken as with sand, for the danger of increasing the fire by a quantity falling into the pots is just as great. It must, of course, be used in conjunction with carbon tetrachloride.

The fourth method, SODA, was very effective. Fires which were believed to be more violent than oil switch fires in the station ordinarily would be, were extinguished effectively. This method has the advantage that a great deal of the equipment is at hand. It is, of course, necessary to kill the apparatus on fire as in all other methods tried (excepting carbon tetrachloride). Additional protection should be given the extinguisher operator, such as grounding the extinguisher and providing the extinguishers with longer hose, the nozzle of which could be mounted on

10. Apparatus for determining conductivity of chemical extinguisher streams.

a varnished stick at an angle of 45 degrees so that the jet may be directed with ease.

The fifth method, FOAMITE, is believed to be the best method under investigation for this kind of work, it being somewhat superior to soda. It has the slight disadvantage of the higher recharging cost of $1.50 against 11c for soda. Even though the apparatus is killed, the protection scheme suggested for soda should be used.

III. High Tension Oil Switch Fires.

The methods under consideration for extinguishing high tension oil switch fires were the same as low tension fires. When the effect of sawdust and sand on the low tension switch was observed, no scheme was, however, attempted by which these could be applied to the high tension switches, as the application of these materials in this case would probably be too complicated to be effected with speed. There remained three methods: 1. Carbon tetrachloride, 2. Soda-acid, 3. Foamite.

CARBON TETRACHLORIDE was first used with the same result in the low tension fires. It was effective on small fires in the pots, but very ineffective on fires extending over the woodwork.

SODA is very effective, and satisfactory, but some method of protection (grounding) similar to that proposed for the low tension fires should be provided, even though the apparatus is killed. It is also necessary to wipe and dry thoroughly any insulator that has been sprayed with soda (or Foamite) before placing same in service again.

FOAMITE is thought to be superior to soda for these fires, as it sticks to the woodwork, extinguishes the fire, and prevents re-ignition; while

in the case of the soda extinguisher some of the effective carbon dioxide is carried away from the fire due to the open bottom in the high tension switches and consequent draft effect. The Foamite extinguisher, too, should be grounded before using even on dead apparatus. The foam is conductive and should be removed from insulators before putting same in service again.

Resumé.

Comparing the above mentioned extinguishers with each other solely with regard to their *extinguishing power,* the tests showed conclusively that the Soda and Foamite were by far the most effective on fires, of all those tried. The liquids used in both of these are, however, *good con-*

H — SUMMARY OF TESTS (Tabulated)

(Transformer Test)

Test No.	Date 1919	Time	Method	Temp. of Oil °C	Amount Liquid Used	Time to Exting.	
I	Nov. 13	4.20 4.25	Tetra-chloride	163	4 Gal.	10 Sec.	Not violent. Easily extinguished. Windy day. Slight increase in smoke and flame when applied.
II	"	4.37½ 4.39		162	None		Went out of its own accord.
III	"	4.53 4.54		160	None		Went out of its own accord.
IV	14	11.04 11.09	Tetra-chloride	200	5 Gal.	5-10 Sec	Flames 6 feet high on ignition. Heavy flames and smoke while burning. Some increase when extinguishing.
V	"	11.29 11.32	Tetra-chloride	210	6 Gal.	10 Sec.	Same.
VI	"	2.05 2.10	Soda	200	2 Gal.	20 Sec.	Extinguished fire; slight increase in smoke and flame. Extinguisher applied at each end of transformer.
VII	"	3.00 3.05	Soda	200	1½ Gal.	12 Sec.	Same, except extinguisher applied at one end only.
VIII	"	3.32 3.37	Water	210	10 Gal.	28 Sec.	Water caused 20-foot flame and great quantities of smoke. Oil thrown.
IX	"	4.12 4.17	Water	200	10 Gal.	11 Sec.	Water caused 20-foot flame and great quantities of smoke. Oil thrown.
X	15	10.33 10.38	Water	175			Went out of own accord.
XI	"	10.50 10.57	Water	190	10 Gal.	20 Sec.	Dense smoke and flame.
XII	"	11.20 11.25		200			Air admitted as fire was about to go out due to lack of air; fire then brightened up.
XIII	"	11.30 11.37		210			Explosion tests. Blew lids up but they settled back. Repeated several times.
XIV	"	2.00 2.05	Foamite	200	About 1¼ gal.		Hot fire. Extinguished O. K. Hottest fire yet.
XV	Dec. 6	11.00 11.05	Tetra-chloride	210	1 Gal.		Could not produce any effect by use of carbon tetrachloride extinguisher.
XVI	"	11.00 11.08	Soda	210	2½ Gal.	60 Sec.	Very hot fire. Extinguisher applied at one end only. Most of fire extinguished in about 25 seconds, but fire in far end held on for 60 seconds.

ductors and will cause flashovers if sprinkled on live insulators; the jets also are *conductors* as long as they stay solid (up to about 4½ feet from the nozzle) and these extinguishers are therefore dangerous to the operator if used in the neighborhood of live equipment. On the other hand, *carbon tetrachloride* and *dry sand* are only effective in special cases, but being insulators might be applied without great danger on live equipment.

Considering the difficulties encountered in these contrary characteristics our recommendations in the individual cases are:

1. TRANSFORMER OIL FIRE. Use soda extinguisher carried through previously installed iron pipes to the air space at top of the transformer

TESTS ON OIL SWITCHES

Low Tension

No.	DATE	TIME	METHOD	AMOUNT FLUID USED	OIL TEMP. °C	REMARKS
I	Nov. 24	1.00 P. M.	Tetra-chloride			Hot fire. Oil soaked wood in bottom of compartment was burned. Tetrachloride Extinguisher refused to operate.
II	"	1.10 P. M.	Foamite	Entire Can		Hot fire. Entire can of Foamite used to extinguish blaze.
III	Dec. 6	11.25 A. M.	Tetra-chloride	Very Little	285 245	Oil in pots ignited. Extinguished by tetrachloride easily.
IV	"	11.20 A. M.	"	1 Qt.	300 260	Oil soaked wood was fired in compartment. Tetrachloride had no effect.
V	"	11.25 A. M.	Damp Sawdust	5 Buckets	High	Two buckets sawdust thrown in and most of fire was put out. Some thrown in pots causing violent fire.
VI	Dec. 8	1.30 P. M.	Tetra-chlo ide	½ Pt.	270 230	Simple fire in pots. Easily extinguished.
VII	"	1.35 P. M.	"	1 Pt.	270 230	Fire under door. Ignited tops of pots and door. Easily extinguished with tetrachloride.
VIII	"	1.45 P. M.	Sand	4 Buckets	300 260	Fire under door and in compartment. Very hot. Reduced by sand.
IX	"	1.55 P. M.	"			Pot burning from VIII. Sand thrown in pots causing burning oil to be thrown all over compartment.
X	Dec. 22	1.30 P. M.	Soda	1¼ gal.		Extremely large fire. Quantities of wood. Fire reduced in 5 seconds. Out in 20 seconds.

High Tension

No.	DATE	TIME	METHOD	AMOUNT FLUID USED	OIL TEMP. °C	REMARKS
I	Dec. 9	2.00 P. M.	Tetra-chloride	Very Little	240	Slight fire in pots. Easily extinguished.
II	"	2.20 P. M.	Foamite	¾ Gal.	300+	Fire built under pots. Very hot oil-soaked wood. Out in 15 seconds.
III	"	2.35 P. M.	Soda	½ Gal.	300+	Similar fire built. Very hot. Out in 20 seconds.
IV	"	2.55 P. M.	"	2½ Gal.	300 +	Similar fire built. Burned 5 minutes and oil constantly applied. Hottest fire. Out in 45 seconds.

tank, but only after the transformer on fire has been taken out of service. Even a fire raging violently should be extinguished in less than one-half minute if two extinguishers are applied simultaneously at *opposite ends* of the tank.

2. Low Tension Oil Fires. If the fire is only a small one in the top of the pot use carbon tetrachloride; otherwise throw the door on the floor, apply first *dry* sand to extinguish any violent fire in the bottom of the compartment; the fire on the top or in the oil pots is then readily extinguished by carbon tetrachloride. *Do not throw any sand into the oil pot,* as this is liable to cause blazing oil to be thrown out of the pots. The switch should be taken out of service, but the neighboring equipment may be left alive.

3. High Tension Oil Fires. If the fire is only a small one in the top of the pot try carbon tetrachloride. If this is not effective, *kill all equipment within reach of the jet* (say 30 ft.), and apply soda, working from the bottom of the fire towards the top.

4. For oil fires on a concrete floor sand is very effective. For open wood fires, Soda should be used if no live electrical conductor is present.

It is realized that it would be desirable to use the same fire fighting equipment on all fires. Unfortunately this does not seem possible at the present state of the art. In consideration of these conditions it would be well to give some of the members of the operating and maintenance department practical instructions in fire fighting.

Foamite is not recommended in spite of its good extinguishing characteristics because it cannot be applied with the same ease to transformer fires as Soda, and it seems undesirable to complicate the fire equipment further simply because of the slightly superior characteristics on oil switch fire.

Tampico Oil Field Fire, July, 1921.

This striking photograph, contributed by the Wm. B. Woodrow Co., of Mexico City (Member N. F. P. A.) shows an oil field fire near Tampico, Mexico, which started on July 19, 1921.

The well in the foreground came in on the morning of July 19 flowing more than 40,000 barrels of oil daily, accompanied by considerable gas. While the crew was still working on this well, the well shown at the right of the picture came in, flowing more than 40,000 barrels daily. The oil was carried by the wind to the boilers of the well seen dimly in the background. The boilers of this well had previously been shut off to avoid endangering the first well but the fire under them was probably not entirely extinguished. The oil was ignited and before the crew could close the valve the heat became so intense that the men were compelled to withdraw. The crew of the well in the foreground managed to get their tools out and were closing the valve when this well caught from the flames and heat of the other. As a result of the heat from the two wells various bunkhouses and six rigs were destroyed. The flames reached a height of 500 to 600 feet. On Sunday, July twenty-fourth, efforts to put out the fire were successful. The valves were luckily uninjured by the intense fire and two men with heads and bodies protected by heavy clothing and followed by two others spraying water from a hose on them succeeded in reaching the valve stems of both wells and closed them.

Fire Resistance of Building Columns as Shown by Test.

By R. E. Wilson
(Member N. F. P. A.)

A series of elaborate tests to determine the fire resistance of bare and fireproofed building columns was carried out during 1917 and 1918 by the Associated Factory Mutual Fire Insurance Companies, the National Board of Fire Underwriters, and the U. S. Bureau of Standards.. A special furnace and testing machine combined was built for the work at the Underwriters' Laboratories, Chicago, by which a column could be subjected to heat while under full load. Because of the large amount of data involved, the results have only just become available, through a detailed report published jointly by the three co-operating organizations. In order to make the results of this important investigation available for use by structural engineers and architects, an analysis is presented herewith in brief form. The conclusions expressed are supported not only by the data given in the full report, but also by the writer's observations as a member of the test party.

The motive for undertaking the tests was the realization that authoritative information on the resistance of building columns to fire exposure was very limited, and that this produced much uncertainty concerning safe methods of construction, reflected in wide variations in building code requirements. Recognizing the need of dependable data on this subject as well as a more accurate basis for determining the value of different types of construction from an underwriting standpoint, the Associated Factory Mutual Fire Insurance Companies in 1910 proposed that a series of tests be made, and secured the co-operation of the National Board of Fire Underwriters, through the Underwriters' Laboratories, and, four years later, of the Bureau of Standards. Preparatory work, including the construction of the furnace and testing machine, began in 1912.

Design of Columns—The essential feature of the tests was to subject the columns to full fire exposure *while under working load*. The furnace and the hydraulic loading ram designed for this purpose are shown in Figs. 1 and 2.

In all, 106 tests were included in the series; 91 of these were fire tests only, while in the remaining 15 tests hose streams were directed against the columns when they were at high temperature. All the columns had an effective length of 12 ft. 8 in. and were designed for a working load of approximately 100,000 lb. as calculated by the following formulas, which are generally accepted in good engineering practice for the various

NOTE. This article originally appeared in the *Engineering News Record*. It is an excellent digest of "Fire Tests of Building Columns," a 389 page volume giving a complete description of the investigations. This book is obtainable from the collaborating organizations or from the executive office of the N. F. P. A.—*Ed.*

materials: Steel columns, $16{,}000\text{-}70l/r$; cast iron, $10{,}000\text{-}60l/r$; Lally columns (steel pipe filled with concrete), $A_s\,(13{,}500\text{-}140l/d)+A_c\,(1{,}000\text{-}11l/d)$; vertically-reinforced concrete columns, $450\,(A_c+15A_s)$; hooped concrete columns, $650\,(A_c+15A_s)$; timber columns, $(1{,}000\text{-}l/80d)$. Both in length and capacity the columns were thus representative of interior columns used in buildings of moderate height.

Type and Protection—The specimens in the fire series consisted of: (1) Unprotected structural steel columns (rolled H, plate and angle, plate and channel, latticed channel, Z-bar and plate, I-beam and channel, latticed angle, starred angle); (2) unprotected round cast-iron columns, vertically and horizontally cast; (3) Lally columns (concrete-filled steel pipe); (4) unprotected timber columns; (5) steel columns partly protected with concrete; (6) protected columns of the various types, with both single and double coverings of metal lath and plaster, and with 2 in. and 4 in. thicknesses of concrete made with different kinds of aggregates, hollow tile of different kinds of clay, and solid gypsum block; (7) reinforced concrete columns with 2 in. integral concrete protection.

The columns and covering materials were obtained from various sources in different sections of the country, including the Chicago, New York, Boston, Cleveland and St. Louis districts, in order to secure samples which were fairly representative of the material used in building construction of the various classes. A large number of auxiliary tests were made on samples of all materials used. The materials of which the columns were constructed generally conformed to accepted specifications for the various kinds of structural material. The steel columns were detailed and fabricated in accordance with good engineering practice. The placing of the various coverings was generally done by experienced workmen in the several trades and the workmanship obtained throughout was fairly representative of that secured in good building practice. All concrete was mixed in a batch mixer. The columns were stored in the testing room and the age of the coverings at time of test ranged between 13 and 18 months.

Manner of Testing—With the exception of three cast-iron columns the steel, cast-iron and reinforced-concrete columns were tested with upper ends fully restrained and lower ends partly restrained. The remaining cast-iron columns, the Lally columns and the timber columns had unrestrained ends. Timber columns were tested with both cast-iron cap and pintle and steel plate cap bearings.

All steel columns were fabricated integrally with a steel head 3 ft. long, protected with concrete, which served to transmit the load from the ram. The other columns were attached to a head which served a similar purpose. The base of each column was embedded for 8 in. in fireproofing, leaving 12 ft. of length exposed to the fire.

A view of the testing furnace with auxiliary equipment and column in place is shown in Fig. 1, and details of the testing machine in Fig. 2.

Procedure in Fire Tests—The columns were subjected simultaneously to the working load and to a fire exposure increasing in accordance with a predetermined time-temperature relation until failure occurred or until they had withstood a test of 8 hr. In the latter event the load was immediately increased under full fire exposure until failure occurred.

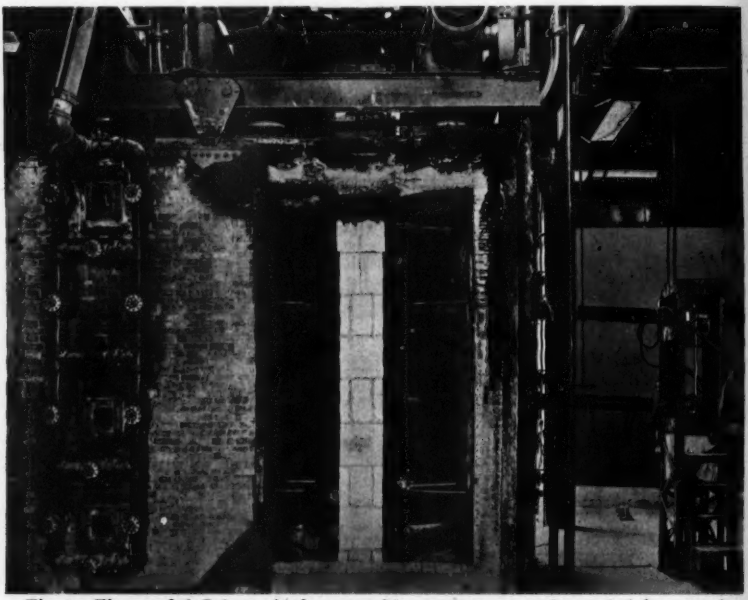


Fig. 1. Fireproofed Column in furnace with pyrometer couples and deformeter in position.

The working load was maintained constant on the column throughout the test by means of a calibrated hydraulic ram of 545,000 lb. capacity. The fire exposure was obtained by placing the columns in a gas-fired furnace with brick walls and concrete block roof, with a combustion chamber 7 ft. square by 12 ft. high. The furnace temperature was regulated closely in accordance with a time-temperature control curve which has been adopted by national technical organizations and testing laboratories. This curve calls for the following temperatures: 5 min., 1,000° F.; 10 min., 1,300° F.; 30 min., 1,550° F.; 1 hr., 1,700° F.; 2 hr., 1,850° F.; 4 hr., 2,000° F.; 8 hr., 2,300° F.

Measurements of the furnace and column temperatures, as well as the vertical and lateral deformation of the columns were taken throughout the tests. All temperatures were measured by electric thermo-couples. For the furnace, four couples were placed at different parts of the combustion chamber and for the columns, from seven to fourteen were placed at three or four levels, both on the column itself and in the covering. The vertical and lateral deformations were measured by means of two horizontal wires, 37 in. apart, attached to each side of the columns and protected with water jacketed sleeves within the furnace and extending to fixed points outside. The vertical movement of these wires was very accurately measured at an intermediate point by means of micrometers. The center deflection of the columns was measured by taking reading with reference to the reflection of point on the wires in polished metal

scale. The effects of the fire on the test column were observed through mica-glazed holes in the furnace walls.

Procedure in Water Tests—The fire-and-water tests began with a predetermined fire exposure based on the ultimate fire resistance of similar columns in the fire series, but not exceeding 1 hr., after which a 1 1/8-in. hose stream at from 30 to 50 lb. nozzle pressure was immediately applied to the highly heated column from a distance of 20 ft. for a period of 1 to 5 min., depending on the type of column covering. The water was applied in succession over the full height of three of its sides.

Summary of Results—The schedule of fire tests giving details of columns and coverings together with the time to failure and the fire resistance period assigned to each column tested is tabulated in Fig. 3. In Fig. 6 are shown typical cross-sections of columns with different protective coverings. The useful fire resistance periods for columns and coverings arranged by groups are given in the table. (See p. 170.) Views of typical columns in the fire series taken after test are shown in Figs. 4, 5, and 7. It is pointed out that a considerable portion of the impairment of the covering, particularly in the region of failure, was in many cases caused by the large deflection of the column which usually occurred at failure.

The time of failure extends from the beginning of the test to the time when the column is unable to sustain the applied working load. The useful fire resistance period has been derived for columns within any group of similar tests by taking *two-thirds the average time to failure* within that group, provided no single test in the group is of shorter duration than the designated period. The one-third reduction is made to allow for all variations due to materials, workmanship and test conditions, and because of the fact that the number of tests in any group was not sufficient to develop the full possibility of difference in results. In assigning these periods consideration was given the results of the fire and water tests, and for the protected columns it was also required that after a 2-min. application of water the column section should not have become exposed in any place and that a sufficient amount of covering should have remained in place to prevent early failure of the column on subsequent fire exposure.

Those columns given the 8-hr. rating withstood the 8-hr. fire test satisfactorily and immediately sustained increased loading of two to three times the working load before failure occurred.

Unprotected Steel Columns—The tests showed conclusively that unprotected structural steel columns of any kind have little value from a fire resistance standpoint and they should not be used in building construction where they could be subjected to a fire of any appreciable degree of intensity or duration, particularly in buildings more than one story high. In all such cases some form of protective covering should be provided. This may be done by filling the reëntrant portions or interior with concrete or by fully covering the steel with concrete, cement plaster on metal lath, hollow clay tile, brick, or solid gypsum block, the kind of material and the thickness of covering depending upon the amount of protection desired.

Unprotected steel columns proved unable to support their calculated working loads after temperatures in the metal of from 900° to 1,100° F.

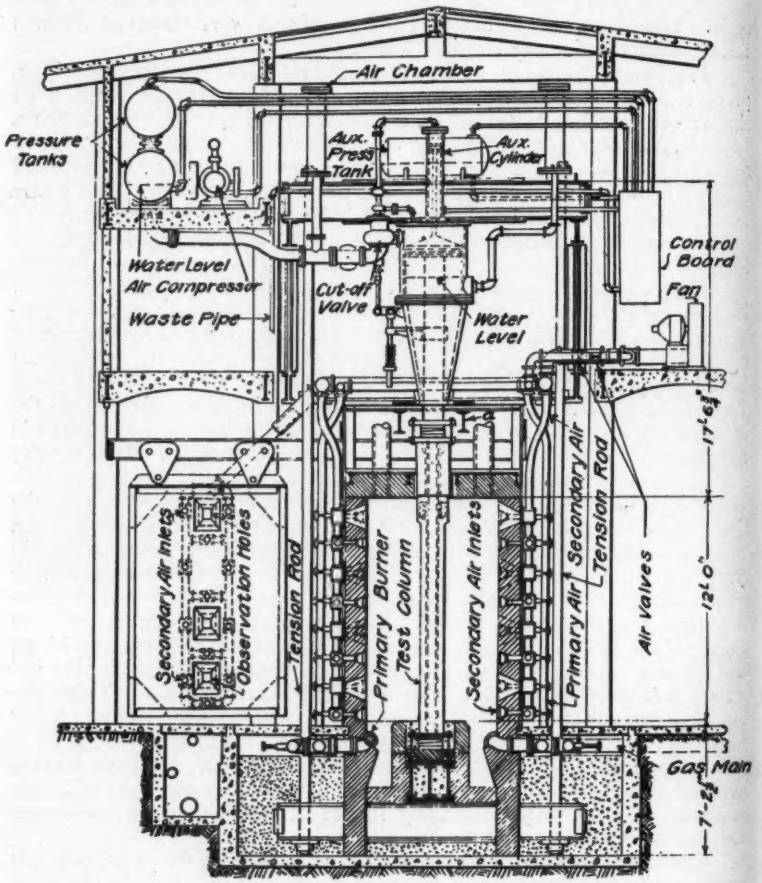


Fig. 2.—*Elevation of testing machine.*

have been reached, the variation being due to the differences in the applied unit loads with different radius of gyration. The total expansion of the steel columns varied from 7/8 in. to 1/8 in., the lower values being due to local heating caused by failure of a portion of the covering. The shape of the steel section appeared unimportant except as it affected the size of the column protection. Slenderness ratio, within the limits of 40 to 80, seems to have had little influence on the fire resistance; the center deflections for columns with these ratios were less than ½ in. up to the time when the column had reached its maximum expansion, though for higher ratios center deflections of nearly 1 in. were noted at this stage. As this deflection might necessitate replacement of a column after a severe fire

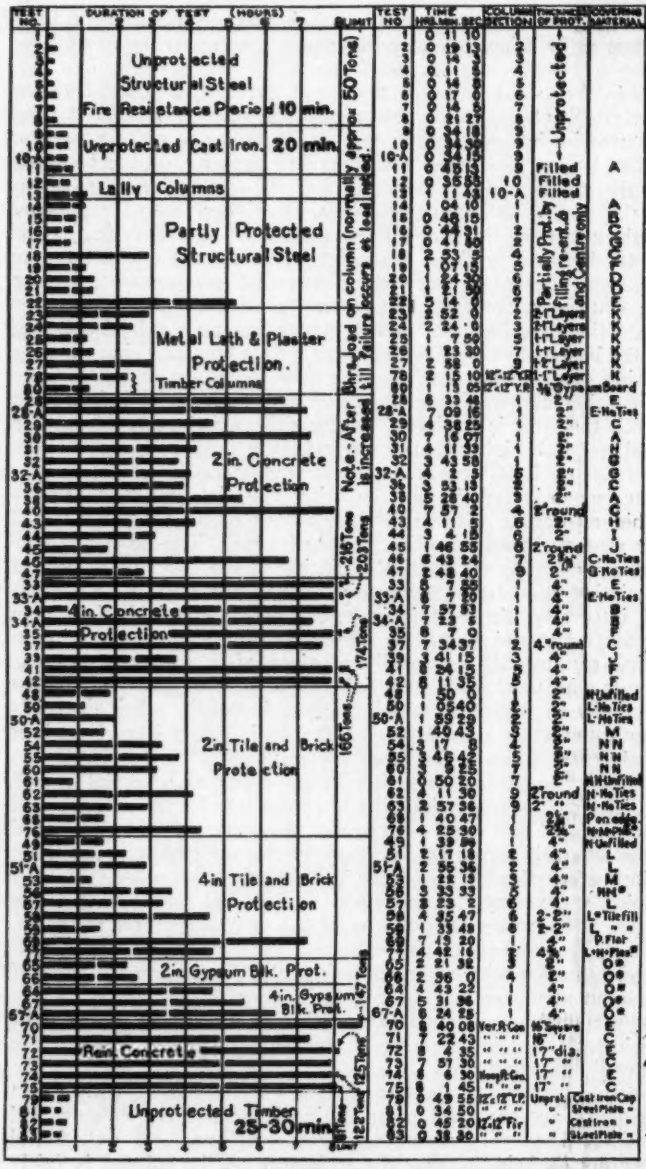
when it would not otherwise be impaired, it is thought advisable to keep the slenderness ratio below 80, especially with the poorer types of protection.

Protected Steel—The value of a column covering depends both on the action of its heat insulating and absorbing properties in retarding the temperature rise in the columns, and on its ability to carry a portion of the column load. The initial load-carrying capacity of the covering varies with the rigidity of the covering and its sectional area as compared with the steel. As heating proceeds the higher rate of expansion of the metal causes the load originally carried by the covering to be transferred to the steel until, at the point of maximum expansion, the metal has become heated to such an extent that compressive yielding takes place, causing a constantly increasing portion of the load to be transferred to the covering, the amount depending on the load-carrying capacity of the latter after the fire exposure. This load-carrying capacity of the covering considerably increases the time to failure of the column, in some cases the increase being over 100 per cent. The lighter unit loads to which the steel is subjected during this period make it possible for the metal to reach higher temperatures before failure; average effective temperatures of 1,400° to 1,500° F. were observed in some cases.

Concrete is considered the best covering material, not only because it gave the highest degree of fire resistance of any of the coverings tested but also for reasons based on other points of view. The necessary materials are usually readily obtained, the placing of the covering is subject to lesser variations due to workmanship than in the cases of materials not applied integrally, the cost is in most cases appreciably less than that of any other material giving the same degree of protection, and concrete covering can usually be readily repaired after moderate fire exposure whereas with most other materials partial or complete replacement is necessary. From a fire standpoint alone, however, other materials make equally satisfactory coverings provided their fire-resistance periods are sufficiently great to meet the necessary demands.

Concrete may be applied to steel columns either as a partial or full protection. The partial protection should completely fill the interior and reentrant portions of the main members. For columns of solid rolled or riveted sections this leaves the faces of the flanges exposed; for those of hollow latticed section the concrete is flush with the outside of rivet heads, completely covering the structural section and lattice bars. The full protection should cover all portions of the main structural members, including lattice bars and splice plates, by not less than the nominal thickness specified, although with round coverings the distance to the edge of the main column members may be reduced somewhat providing the resulting cross-sectional area is not less than that of a covering of the same nominal thickness. A 1-in. covering is sufficient protection for brackets and other details of small area.

For concrete protections the two variables which most greatly affect the fire resistance are the total cross-sectional area of the column and covering and the kind of concrete aggregate employed. It was found that all other details being similar the resistance of the column is fairly proportional to its cross-sectional area. For this reason minimum areas


DURATION OF TEST (HOURS)
Unprotected Structural Steel
Fire Resistance Period 10 min.
Unprotected Cast Iron. 20 min.
Lally Columns
Partly Protected Structural Steel
Metal Lath & Plaster Protection.
Timber Columns
2 in. Concrete Protection
4 in. Concrete Protection
2 in. Tile and Brick Protection
4 in. Tile and Brick Protection
2 in. Gypsum Blk. Prot.
4 in. Gypsum Blk. Prot.
Reinf. Concrete
Unprotected Timber
25-30 min.
Burning
Burned
Burned
Burned

are specified in the table of useful fire-resistance periods, and areas at least equal to these minimums should be used to obtain the rated periods.

Character of Covering Concrete—The difference in protection afforded by the various kinds of concrete is very great. The different kinds of aggregate ordinarily used can be divided in this respect into three groups as follows:

1. Siliceous gravel or other siliceous materials especially those containing a high percentage of chert, which is a non-crystalline form of silica containing water in chemical combination. Concrete made with this aggregate was found to be subject to excessive cracking and spalling on fire exposure, which greatly reduced its fire resistance as compared with other kinds of concrete. It is not recommended for use as a covering material when other kinds of aggregate can be obtained, and should not in any case be used for partial protections. (Tests subsequently conducted at the Pittsburgh Laboratories of the Bureau of Standards indicate that the fire-resistive properties of coverings made of siliceous gravel concrete can be appreciably increased by placing a reinforcement of expanded metal lath in the concrete. This procedure may sometimes be necessary where it is impracticable to use other kinds of aggregates).

2. Trap rock, granite, sandstone or hard coal cinders. Concretes with these aggregates all offer approximately the same amount of fire resistance, their periods being intermediate between those of high siliceous and of limestone aggregate concretes. Trap rock is slightly preferable provided it is a true trap. Trap rock and cinder concrete developed no spalling in the test although there was a slight amount of cracking during the latter part of the tests. The granite and sandstone cracked and spalled to some extent principally at the corners, the standstone showing these effects to the greater degree. A slight amount of fusion of the trap and granite concretes took place after tests of more than 7 hr. duration, but this had no apparent influence on the results.

3. *Limestone or Limestone Gravel*—Concrete in which these materials are used for coarse aggregate gives by far the best results. No spalling and very little cracking occurred during the tests. All of the 4-in. limestone protections withstood the 8-hr. test and while still exposed to fire sustained ultimate loads of about three times the working load. To obtain the full value of this kind of protection the material should be clean and should not contain more than 5 to 10 per cent of clayey impurities nor more than 10 per cent of free silica.

KEY TO COVERING MATERIALS (FIG. 3)

a—1: 2: 4 limestone gravel concrete.
b—1: 2: 4 N. E. granite concrete.
c—1: 2: 4 N. Y. trap concrete.
d—1: 3: 5 N. Y. trap concrete.
e—1: 2: 4 Chicago limestone concrete.
f—1: 3: 5 Chicago limestone concrete.
g—1: 2: 5 hard-coal cinder concrete.
h—1: 2: 4 Cleveland sandstone concrete.
i—1: 3: 5 Cleveland sandstone concrete.
j—1: 2: 4 siliceous gravel concrete.
k—Metal lath and cement plaster.
l—Surface clay tile.
m—Shale tile.
n—Medium-hard semi-fire clay tile.
nn—Hard semi-fire clay.
o—Solid gypsum blocks.
p—Common clay brick.

NOTE.—Total length of lines in chart shows time to failure in each test; break in line indicates useful fire resistance.

All partly protected columns tied with vertical and horizontal wire ties. Concrete protections tied with No. 5 B & S gage steel wire wound spirally on 8-in. pitch unless otherwise noted. In tile-protected columns concrete filling placed between tile and column unless otherwise noted. Tests marked with asterisk following letter denoting covering indicate that tile or gypsum block was tied with metal ties in horizontal joints; otherwise tied with wire around outside each course.

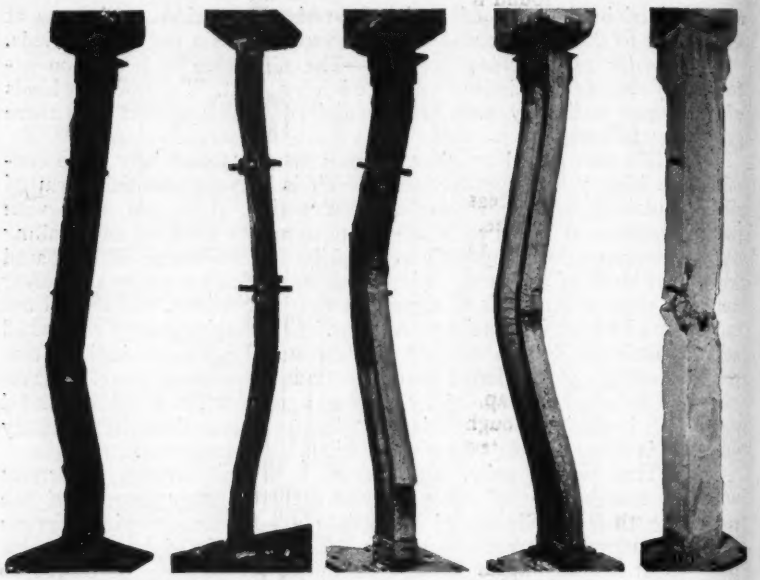


Fig. 4. Condition of unprotected and partly protected columns after test. Rolled H (No. 1); Cast Iron (No. 9); Rolled H, granite concrete covering, (No. 15); Latticed column, limestone concrete covering, (No. 22); Steel column, metal lath and plaster covering, (No. 26). Note little damage to covering.

The sand used with the various coarse aggregates is of minor importance provided it meets the requirements of a good concrete sand, but, for best results the use of highly siliceous sands should be avoided in combination with limestone or limestone gravel.

The proportions of the concrete mixture appeared to affect the fire resistance to some extent where full protections were employed and for this reason a mixture not leaner than 1 :6 is recommended.

The tests indicated no appreciable advantage in shape of covering, whether round or square. This fact is interesting because it has been somewhat commonly believed that the round covering is preferable due to corner cracking of the square coverings. Although this cracking occurred in the tests it did not apparently affect the results to any extent, and where concrete subject to severe cracking and spalling was used no apparent retardation of this action was observed with the round covering.

Wire ties are recommended with all types of concrete protection and were found to be especially desirable where the concrete is subject to cracking and spalling as in the case of siliceous and sandstone aggregates. They are also needed to hold in place portions of concrete damaged by fire when subsequently subjected to the action of hose streams as was demonstrated in the fire and water tests.

A single covering of metal lath and plaster at least 1 in. thick may be used on steel columns to obtain a degree of fire resistance somewhat

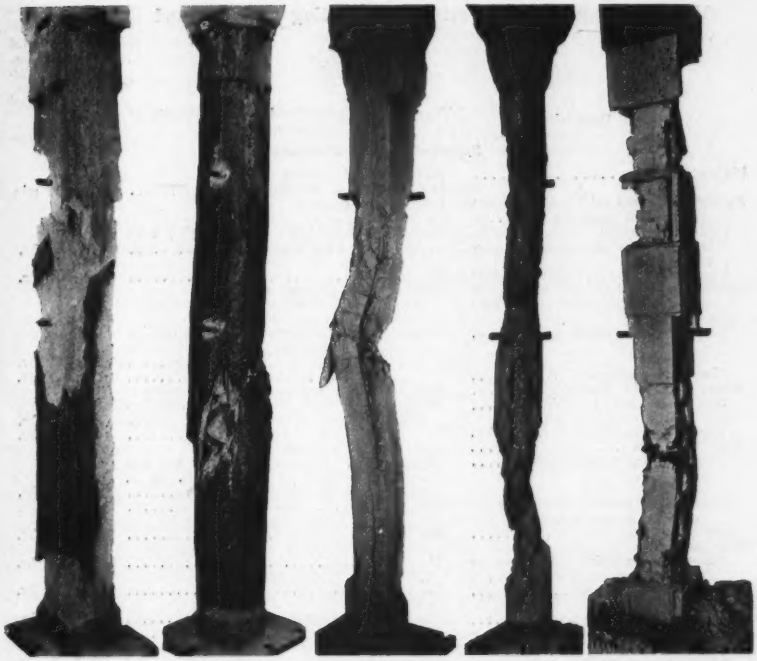


Fig. 5. Condition of steel columns with full concrete protection after tests. 4 in. limestone concrete (No. 33). No cracking or spalling before failure. 2 in. trap concrete (No. 40). Note fusion. Sandstone concrete (No. 44). Note corner cracking. Siliceous gravel concrete (No. 45). Note excessive cracking and spalling. 4 in. gypsum block (No. 66). Note cracking and shrinkage.

greater than that of unprotected timber or cast-iron columns, and two coverings, each at least 7/8 in. thick, were found to double the amount of resistance. This material, while having no load-carrying capacity, preserves its integrity very well under the action of both fire and hose streams. The mixture proportion used in the tests (1:1/10:2½ cement, hydrated lime, sand) is recommended, and though the details of application are unimportant the thickness of covering appreciably affected the results. For this reason the heaviest layer thicknesses which it is practicable to apply should be used. The effect of the air space between coverings, while not fully determined, is not believed to be of any appreciable value.

Tile Coverings—The amount of fire resistance afforded by single-layer coverings of 2-in., 3-in., or 4-in. hollow clay tile was found to be comparatively small, and even with medium hard semi-fire clay tile (which was the best kind employed in the tests) it is equivalent to only that of a single layer of metal lath and plaster. If it is desired to use tile and a greater amount of fire resistance is necessary, the tests showed that this can be obtained by placing concrete filling in the spaces between

Useful Fire Resistance Periods of Building Columns and Coverings.

Type of Protection	Type of Column Section and Details of Protection	Minimum Area of Solid Material Sq. In.	Useful Fire Resistance Period
Structural Steel Columns			
Unprotected	**Any type of section** Minimum metal thickness 0.20 in.	8	10 min.
Partly Protected by filling reentrant spaces with concrete	**Solid steel section**		
Limestone, trap rock, granite, sandstone or hard coal cinder aggregate	Mixture 1:6 or 1:8. Concrete tied with vertical and horizontal ties	35	½ hr.
Limestone or trap rock aggregate	Do	60	¾ hr.
Partly Protected by filling reentrant spaces and interior with concrete	**Hollow latticed steel section**		
Trap rock aggregate	Mixture 1:6. Concrete extends to outside of rivets, covering lattice and main members	120	2 hr.
Limestone aggregate	Do	120	3½ hr.
Metal lath and plaster	**Any type of section**		
One covering (1 in. thick)	Mixture 1:1/10:2½ Portland cement, hydrated lime and sand	40	¾ hr.
Two coverings (each ¾ in. thick)	Do	80	1½ hr.
2-in. concrete	**Any type of section**		
Siliceous gravel aggregate	Mixture 1:6. Concrete tied with not less than equivalent of No. 5 (B. & S. gage) wire on 8-in. pitch	100	1 hr.
Trap rock, granite sandstone or hard coal cinder aggregate	Do	100	2½ hr.
Limestone aggregate	Do	100	4 hr.
3-in. concrete			
Trap rock, granite, sandstone or hard coal cinder aggregate	Do	140	3½ hr.
Limestone aggregate	Do	140	6 hr.
4-in. concrete			
Siliceous gravel aggregate	Do	200	2½ hr.
Trap rock, granite, sandstone or hard coal cinder aggregate	Do	200	5 hr.
Limestone aggregate	Do	200	8 hr.
2-in., 3-in. and 4-in. hollow tile	**Solid steel section**		
*Medium hard semi-fire clay with no filling	Outside wire ties. Mortar joint between tile and column flanges	80	1 hr.
Surface clay or shale tile with concrete filling on web sides	Do. Filling serves as partial concrete protection	100	1 hr.
Extra heavy surface clay with filling on web sides	Do	160	1½ hr.
	Any type of section		
Semi-fire or surface clay with filling on all sides	Outside wire ties. Filling serves as full concrete protection at least ½-in. thick	160	2 hr.
Do	Metal ties in horizontal joints, otherwise do	160	2½ hr.
2 layers 2-in. hollow tile	**Solid steel section**	..	.. ..
Surface clay with hollow tile filling	Metal ties in horizontal joints. Mortar joint between tile and column flanges and webs	240	3 hr.
Do	Outside wire ties, otherwise do	240	1 hr.
2½in. common brick	**Any type of section** Brick set on edge and end. Brick filling	140	1 hr.
3½-in. common brick	**Any type of section** Brick laid flat. Brick filling	240	5 hr.
2-in. solid gypsum block	**Any type of section** Gypsum block or poured gypsum filling; metal ties in horizontal joints; mortar joint between blocks and column flanges	130	1½ hr.
3-in. solid gypsum block	Do	180	2½ hr.
4-in. solid gypsum block	Do	240	3½ hr.
Round Cast-Iron Columns			
Unprotected Unfilled	Minimum wall thickness 0.60 in.	12	25 min.
Unprotected Interior filled with concrete	Do	35	½ hr.
Metal lath (high ribbed) and plaster One covering; (1½ in. thick)	Mixture 1:1/10:2½ Portland cement, hydrated lime and sand; ½-in. air space	60	2 hr.

*Any other kinds of clay tile not recommended, as tests indicate periods of ½ hr. or less.

2-in. concrete Trap rock, granite or hard coal cinder aggregate	Mixture 1:6 or 1:7. Concrete tied with not less than equivalent of No. 5 (B. & S. gage) wire on 8-in. pitch	70	2 hr.
2-in. hollow tile Porous semi-fireclay	Outside wire ties. Mortar joint between tile and column	70	2 hr.
Unprotected	**Steel pipe filled with concrete** Concrete mixture 1:1½:3	45	25 min.
Unprotected	**Steel pipe filled with concrete and reinforced in fill with structural shapes.** Concrete mixture 1:1½:3	55	¾ hr.
	Reinforced Concrete Columns		
2-in. integral concrete protection	Round or square vertically reinforced or hooped reinforced. Concrete mixture 1:6. Trap rock aggregate	220	5 hr.
2-in. integral concrete protection	Round or square vertically reinforced or hooped reinforced. Concrete mixture 1:6. Limestone aggregate	220	8 hr.
	Timber Columns		
Unprotected	Unprotected steel plate cap bearing	120	25 min.
Unprotected	Unprotected cast iron cap and pintle bearing	120	½ hr.
½-in. gypsum wall board	Cast iron or steel plate cap bearing, protected	140	¾ hr.
Metal lath and plaster One covering (1-in. thick)	Cast iron or steel plate cap bearing, protected. Mixture 1:1/10:2½, Portland cement, hydrated lime and sand; ¾-in. air space	160	1½ hr.

the column and tile after the tile is set. The use of tile without this filling is not recommended except in case of medium hard semi-fire clay, since with the other kinds of tile tested the cracking and spalling under fire allows the heat to reach the steel and the application of hose streams carries away large portions of the impaired covering. When concrete filling is used the column so filled is essentially a partly or fully protected column with an additional protection of tile. The concrete not only serves as a protection but also aids in holding the tile in place by adhesion and for this reason should always be placed after the tile is set.

Semi-fire clay tile of medium hardness has the best fire resistive properties, developing little cracking and spalling under fire. Hard-burned semi-fire clay, surface clay and shale follow in the order named, the latter cracking severely with spalling of outer shells early in the tests. The overall thickness of the tile appeared to have no appreciable influence on the results, and the mechanical strength was of no importance. This latter fact is of particular interest since some specifications based on mechanical strength would rule out tile of the better fire-resistive properties.

As a result of comparable tests, the use of metal ties in the horizontal joints is recommended as better than use of outside wire ties, and with tile subject to severe cracking and spalling the former method adds appreciably to the period of fire resistance. Outside plastering is not believed to be of much value, though this point was not determined for plastering which had aged over six weeks.

Brick and Gypsum—A covering of common clay brick laid flat with brick filling to give a nominal protection of 4 in. in thickness was found to afford a fire resistance equivalent to 2 in. of concrete with aggregates of trap, granite, sandstone or hard-coal cinders. The brick remained in place throughout the test though fluxing after 4½ hr. Brick laid on end and edge to give a 2-in. protection afforded only about one-quarter as

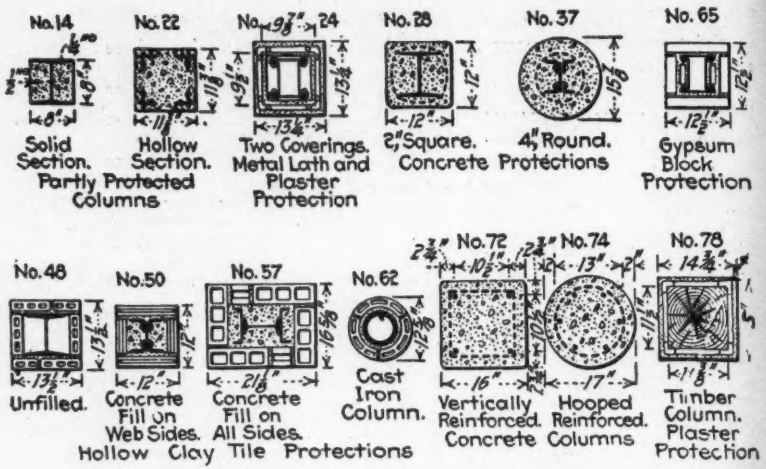


Fig. 6. Typical Sections of Columns and Coverings.

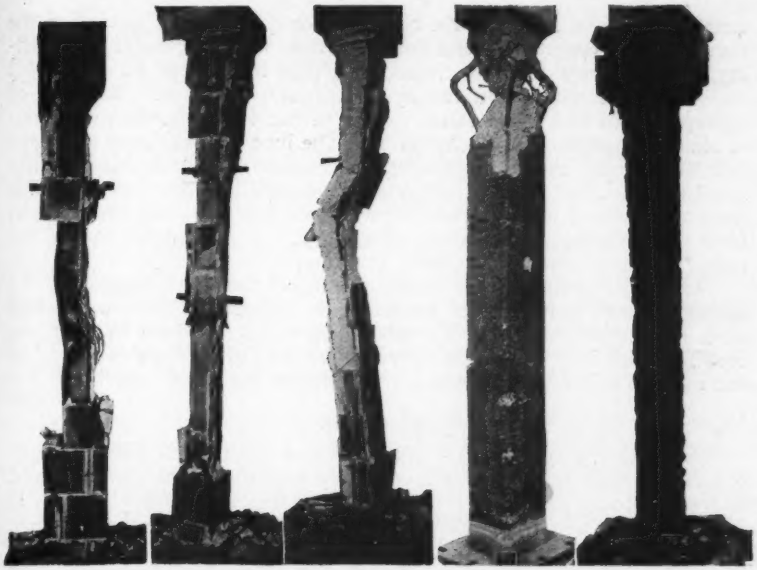
great protection as brick laid flat, the large decrease being due to the instability of the units.

Solid gypsum block with gypsum filling and metal ties in the horizontal joints makes a very satisfactory covering material, the 2-in. blocks giving fire resistance periods equal to those obtained with the better kinds of tile with concrete filling and the 4-in. equivalent to a 3-in. protection of concrete made with trap, granite, sandstone or cinder aggregates. Failure is due to checking, shrinkage and disintegration of the blocks under fire with consequent loss of stability of the blocks, and not to normal heat transmission through the covering. In the latter respect gypsum showed itself to be by far the best insulating material. Its action under the application of hose streams in the fire and water tests was quite satisfactory, the strength of the blocks being well retained below the region of calcining.

Cast-Iron Columns—Unprotected cast-iron columns offer about twice as much resistance to fire as unprotected structural steel columns and nearly as much as timber columns. No variation is caused by end restraint. The application of hose streams to heated columns, although inducing large permanent deflections, does not cause the columns to lose their load-carrying ability. Filling the interior with concrete increases the resistance offered to an amount approximately equal to that of timber columns. Protections of metal lath and plaster, concrete or hollow clay tile increase the fire resistance very materially, the action of the various coverings being similar to that with steel columns.

Lally Columns—The plain Lally column (concrete-filled steel pipe) was found to offer approximately the same amount of fire resistance as a cast-iron column. The reinforced Lally column has nearly twice this amount of resistance.

Timber Columns—Timber columns with cast-iron cap and pintle or steel-plate cap bearings have fire resistance periods of 2½ to 3 times that



49 52 55 70 79

Fig. 7. Condition of steel columns with gypsum and hollow tile protection after test. 4 in. medium hard semi-fire clay tile, no filling (No. 49). Note thermocouple wires. 2 in. shale tile, concrete filling on web sides (No. 52). 2 in. hard semi-fire clay tile, concrete filling on all sides (No. 55). Reinforced concrete column, limestone concrete, 2 in. over steel (No. 70). Failure due to overloading after 8 hr. exposure, no spalling before. Timber column, unprotected, cast iron cap and pintle bearing, (No. 79). Note cap failure.

of unprotected structural steel and slightly greater than that of unprotected cast-iron columns. The full fire resistance of the column itself is not developed with either type of cap, failure being due in every case to excessive heating of the wood at the upper bearing under the metal cap with resultant crushing and brooming of the fibers and ultimate cracking or slipping of the caps. This indicates that with a column cap of a material that will sufficiently protect the bearing surface, a timber column will withstand considerably longer fire exposure before failure and periods from two to three times as great could be expected. It is understood that fire tests being made by the National Lumber Manufacturers Association with a newly devised cap confirm this deduction.

Protections of a 3/8-in. layer of gypsum wall board and of a single 1-in. covering of cement plaster on metal lath which also covered the cap increased the fire-resistance periods from about 50 to 200 per cent respectively. In applying such coverings, however, consideration should be given to the danger from dry rot, and steps taken to prevent possibility of deterioration of the timber from this source.

Reinforced-Concrete Columns — The reinforced-concrete columns tested included both square and round vertically reinforced and round hooped reinforced types with steel covered by 2-in. integral protection. The concrete mixture was 1:6 with coarse aggregates of both trap rock and of limestone, and definite conclusions are made for these two ma-

terials only. The action of the concrete was quite similar to that of the same kinds of concrete as used for protections of steel columns, no spalling and but a very few fine cracks developing throughout the tests.

The fire resistance offered by the columns varies with the kind of aggregate used and is equivalent to that of the 4-in. concrete protections of similar aggregates on steel columns. The limestone has been given the full 8-hr. rating, as reinforced-concrete columns of this aggregate withstood the 8-hr. fire test and immediately sustained loads of two to three times the working load. In no case was there any apparent effect due to form of reinforcement or shape of column and neither the square nor round columns showed appreciable cracking.

In the fire-and-water test series concrete columns with siliceous gravel aggregate were included, and its action was similar to that observed in other tests of this material. Considerable crushing, cracking and spalling occurred with both square and round coverings of this material, and in one case the spiral hooping was exposed before the end of one hour.

Conclusions.

In conclusion it may reasonably be stated that the test conditions are believed to have conformed quite generally with those which are obtained in good building practice. It is appreciated that the number of tests in certain groups was not sufficient to obtain the full range of variation. It is believed, however, that the reductions made in assigning fire resistance periods are sufficient to allow for all differences which may occur if reasonable care is taken to suitably identify materials and classify them in the proper groups and also to obtain a good grade of workmanship. The loading and bearing conditions obtained are considered as severe as those found in usual practice except that in some cases it may not be possible to duplicate the full bearing conditions of the concrete coverings. This advantage is, however, slight, as concrete will develop bond in a comparatively short length and whatever difference may occur is discounted by the reductions applied in assigning periods. In placing all coverings, however, they should be applied so as to obtain as full and continuous bearings as possible.

The fire exposure as determined by the standard time-temperature control curve which was employed is considered to be fully equal to, and probably greater than, that to which the building columns would be subjected in practice except where large quantities of highly combustible material are involved. The exposure was of high intensity and continuous throughout the test, a condition which would seldom be duplicated or exceeded even under conflagration conditions.

With proper attention to the various features which have been noted above, it is believed that columns and coverings of the various types tested will be able to safely support their designed working loads throughout building fires of durations corresponding to their rated fire resistance periods and in the great majority of cases the columns so exposed will not have been permanently injured.

Air Lock of Gravity Tank from Pressure Tank Supply

Joint Article by several N. F. P. A. Members.

Recently Mr. Henry F. Whitner of Atlanta informed the National Board of Fire Underwriters of his apprehension that the air pressure which remains after exhaustion of the water from the pressure tank would hold shut, under certain conditions, the check valve in the gravity tank discharge, thus rendering valueless this supply to the sprinkler equipment.

Reference of the communication to the Committee on Automatic Sprinklers resulted in a series of tests at Montreal, New York and Chicago, and to considerable correspondence with other inspection departments. For the information of the membership generally, this article has been prepared jointly by E. P. Boone, J. H. Brumbaugh and C. L. Scofield; but there has been no formal action as yet by the Committee on Automatic Sprinklers.

In a combination of pressure and gravity tanks as water supplies to a sprinkler equipment, and with the pressure tank filled two-thirds with water and an initial air pressure of 75 pounds, an air pressure of approximately 15 pounds remains after the discharge of the water. With only a slight difference in the elevations between the gravity and pressure tanks, and the two feeding near the highest point of the system into a common discharge or "dead riser" to the base of the system, Mr. Whitner points out the possibility of an air lock in this dead riser, if sprinklers open only on upper floors. This would be due to the pressure from the head of water in the sprinkler riser, below the level of the opened sprinklers, balancing or overcoming that of the air pressure in the dead riser. The elevation of the gravity tank above that of the pressure tank being insufficient to overcome the air pressure thus locked in the dead riser, and without vent for this air, the check valve in the gravity tank discharge at the upper level would be held shut. The same condition would not apply if the opened sprinklers were in a lower story where there would not be a sufficient head of water to overcome the air pressure. Nor would it apply with other arrangements of water supplies, quite extensively employed. There is no recognition of such a contingency in either the sprinkler or tank regulations and to save in the cost, this method of installation has been used frequently. Mr. Whitner's claim, therefore, merited the attention which it has received and the result of the tests mentioned above are appended in the order of receipt.

Fire Experience Under This Condition of Installation.

The fire report blank used in connection with the N. F. P. A. records

does not include any query to cover such a contingency as outlined, and no positive statement can be made that it has never caused unfavorable action; but so far as the Executive Office at Boston can determine from a search of the fire records, and also from direct inquiry by the authors of this article to inspection departments in those fields where pressure tanks have been largely used, there has been no failure of a gravity tank to function after the exhaustion of the pressure tank supply. The great majority of the fires have been controlled solely by the pressure tank supply and the percentage of fires occurring on lower floors or under conditions of installation where there would be no air lock, would also tend to reduce the possibility of failure. It must be recognized, however, that there is such a possibility and some inspection departments have already taken steps to secure zero air pressure on the exhaustion of the water from pressure tank by raising the water level, reducing the air pressure, or both. To illustrate, there is given copy of print issued by the Associated Factory Mutuals which indicates their action to overcome the difficulty by lowering the air pressure and raising the water level. Incorporated in report of tests also appear several suggestion offered by C. W. Mowry of the Factory Mutual Laboratories. To save repetition there has been omitted some explanatory matter from the details of the several tests appended, but without destroying their value, it is impossible to avoid some repetition.

Montreal Tests

April, 1921.—Conducted jointly by the Canadian Automatic Sprinkler Association and the Canadian Fire Underwriters' Association; reported by C. L. Scofield.

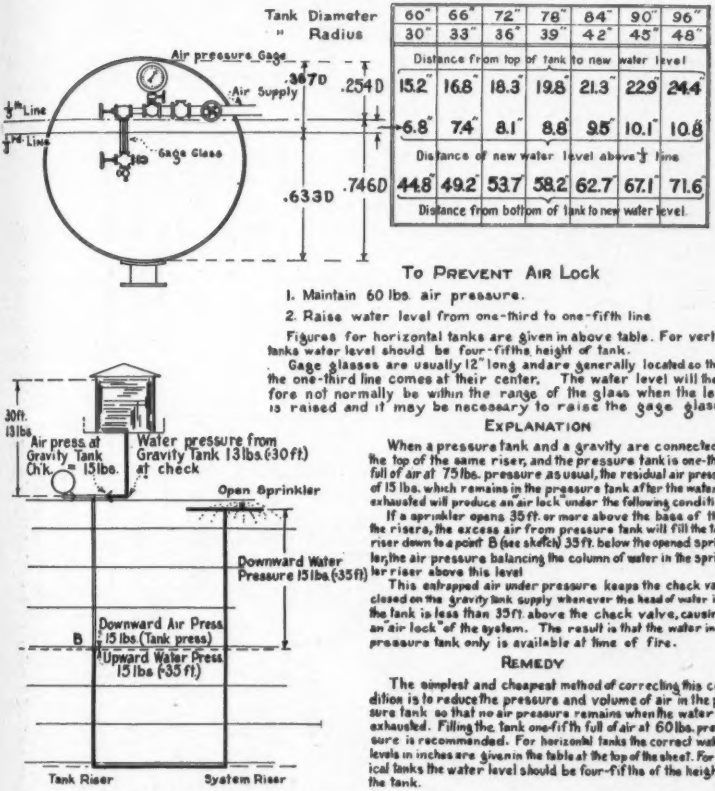
The first Montreal test was held on Friday, April 1st, 1921. The water supplies consisted of two pressure tanks of approximately 6000 gallons total capacity each; a 6-inch connection from 10-inch city main, seventy-five pounds (75 lbs.) and two gravity tanks 4500 gallons and 8000 gallons capacity, the smaller located immediately over the larger, and elevated respectively nineteen feet (19 ft.) above and about level with the main top sprinkler lines and the top of the highest tank elevated twenty-six feet eight inches (26 ft. 8 ins.) above the bottom of the pressure tanks. The accompanying illustration shows details of the system as applying to the test.

Method of Conducting Test.

As water discharged at the far end of the plant could be most readily disposed of, a 1 1/4-inch pipe was connected with the sprinkler system in the top story and run outdoors near the ceiling level. The pipe terminated in two discharges, one an open 1 1/4-inch outlet, extending 3 1/2 feet horizontally beyond the building line, and the other a 3/4-inch pipe extending 5 feet with an opened sprinkler head upright at the end. Each pipe was controlled by a valve inside the building.

Inspectors from the Canadian Fire Underwriters' Association were stationed at the pressure gauges noted in illustration also to watch the water level in the gravity tanks and in the pressure tank so long as it could be read, and at the indicator post valve controlling the city supply.

PRESSURE TANK ADJUSTMENT
To Prevent Air Lock

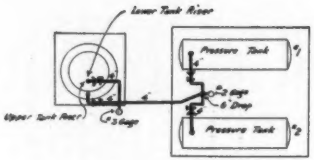

Tank Diameter
" Radius
60" 66" 72" 78" 84" 90" 96"
30" 33" 36" 39" 42" 45" 48"
Distance from top of tank to new water level
15.2" 16.8" 18.3" 19.8" 21.3" 22.9" 24.4"
6.8" 7.4" 8.1" 8.8" 9.5" 10.1" 10.8"
Distance of new water level above ⅓ line
44.8" 49.2" 53.7" 58.2" 62.7" 67.1" 71.6"
Distance from bottom of tank to new water level.
Air pressure Gage
.367D
.254D
Air Supply
⅓rd Line
⅔rd Line
Gage Glass
.633D
.746D
To Prevent Air Lock
1. Maintain 60 lbs. air pressure.
2. Raise water level from one-third to one-fifth line
Figures for horizontal tanks are given in above table. For vertical tanks water level should be four-fifths height of tank.
Gage glasses are usually 12" long and are generally located so that the one-third line comes at their center. The water level will therefore not normally be within the range of the glass when the level is raised and it may be necessary to raise the gage glass.
EXPLANATION
When a pressure tank and a gravity are connected to the top of the same riser, and the pressure tank is one-third full of air at 75 lbs. pressure as usual, the residual air pressure of 15 lbs. which remains in the pressure tank after the water is exhausted will produce an air lock under the following conditions:
If a sprinkler opens 35 ft. or more above the base of the risers, the excess air from pressure tank will fill the tank riser down to a point B (see sketch) 35 ft. below the opened sprinkler, the air pressure balancing the column of water in the sprinkler riser above this level
This entrapped air under pressure keeps the check valve closed on the gravity tank supply whenever the head of water in the tank is less than 35 ft. above the check valve, causing an "air lock" of the system. The result is that the water in the pressure tank only is available at time of fire.
REMEDY
The simplest and cheapest method of correcting this condition is to reduce the pressure and volume of air in the pressure tank so that no air pressure remains when the water is exhausted. Filling the tank one-fifth full of air at 60 lbs. pressure is recommended. For horizontal tanks the correct water levels in inches are given in the table at the top of the sheet. For vertical tanks the water level should be four-fifths of the height of the tank.
30 ft.
13 lbs.
Air press. at Gravity Tank Chk. = 15 lbs.
Water pressure from Gravity Tank 13 lbs. (30 ft) at check
Open Sprinkler
Downward Water Pressure 15 lbs. (35 ft)
B
Downward Air Press. 15 lbs. (Tank press)
Upward Water Press. 15 lbs (-35 ft)
Tank Riser
System Riser

Sheet issued by Associated Factory Mutual Fire Insurance Companies giving method to prevent air lock.

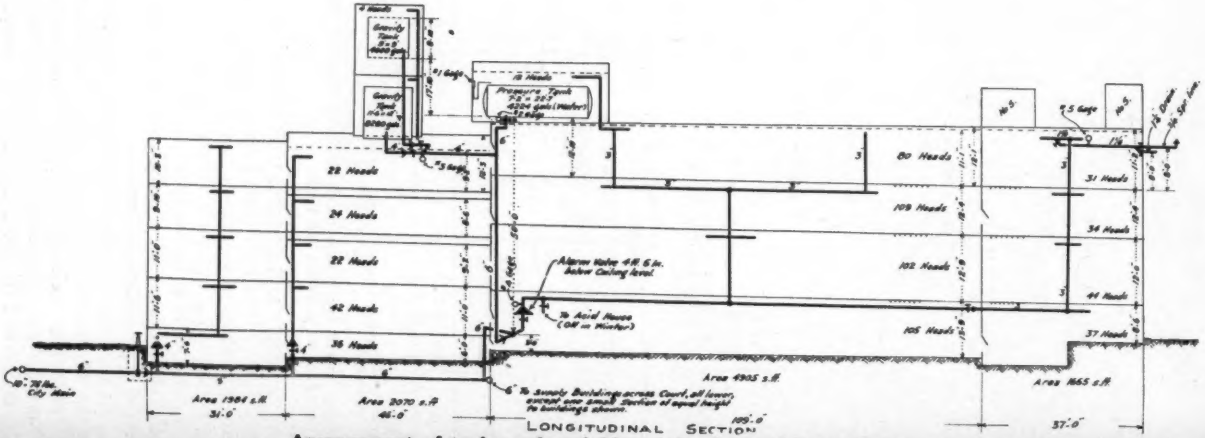
The city supply and pressure tank marked No. 2 were shut off during the test. The test was witnessed by representatives of the Canadian Automatic Sprinkler Association, Canadian Fire Underwriters' Association, Mr. George H. Greenfield, Chairman of the Canadian Committee, N. F. P. A., and others, including the writer. Tarpaulins loaned by the Montreal Fire Department were placed at the windows near the test pipe to prevent any entrance of water.

At the start of the test, the air pressure stood at eighty pounds at the top of the pressure tank, being the pressure normally maintained in this system, and eighty-three pounds at the floor level of the tank house in the cross connection between the two pressure tanks above referred to.

At the end of forty-nine minutes the pressure on the pressure tank



PLAN OF TANK CONNECTIONS



LONGITUDINAL SECTION

Arrangement of tanks and sprinkler piping in the Montreal tests.

gauge had been reduced to twenty and one half pounds. The 1 1/4-inch test outlet was then shut off and the discharge made solely through the opened sprinkler head. The pressure, however, reduced so slowly that at the end of fifteen minutes the 1 1/4-inch outlet was again put in service, and ten minutes later the last water could be heard leaving the pressure tank, the air pressure standing at sixteen pounds at the pressure tank gauge and one half pound higher at the cross connection.

The gauges remained at this pressure but the discharge of water through the opened sprinkler soon ceased. There still continued a dribble through the 1 1/4-inch outlet. The water in the gravity tanks did not lower, but the dribble persisted and was allowed to continue for thirty-five minutes. It was of no value for sprinkler supply and did not come from the gravity tanks, as the water in same was not lowered. It is thought to have been due to a leak past the gate valve in the city supply although there was evidently a very slight leak past the closed gate valve on pressure tank No. 2. It was so slight, however, as not to show any effect on the system gauge of pressure tank No. 2, but the water level in the tank was apparently affected a slight fraction of an inch.

At the end of the thirty-five minute period above referred to, the gate valve in the discharge from pressure tank No. 1 (the emptied tank) was closed, and the air released in the dead riser by removing the gauge from the cross connection pipe between the two pressure tanks. When the air pressure had been reduced to ten pounds on the pressure tank gauge, the water in the upper gravity tank began to lower and was discharged through the 1 1/4-inch outlet and also the opened sprinkler head. By opening the valve in the discharge of pressure tank No. 1, (the emptied tank) the air pressure in the dead riser was increased, which caused the check in the gravity tank to close. Before closing, however, air was forced up through the water in the higher gravity tank in sufficient volume to spill water over the top. On again closing the gate valve in the pressure tank discharge, and venting the air as previously, the water from the gravity tank supply again flowed. It was readily determined when the tank water was discharging, not only by the lowering of the water in the tank, but from its dirty appearance at both discharges.

Summary.

Elevation of test pipe above level of alarm valve was approximately thirty-seven feet = sixteen pounds pressure, sufficient to balance the air pressure remaining in system.

Elevation of top of gravity tank (water level two inches below top) above bottom of pressure tank twenty-six feet eight inches (17 ft. 10 in. plus 8 ft. 10 in. of water = 11.6 lbs.) was not sufficient to overcome the sixteen pounds air pressure remaining in system, showing the air lock. The check valve in gravity tank supply opened when air was vented sufficiently to reduce pressure to ten pounds — probably a little before, as it took a short time for water to travel the distance from tank to test pipe.

The water that continued to dribble through the 1 1/4-inch outlet on the test pipe, after the pressure tank was exhausted, has not been accounted for; but as previously stated, is thought to have been due to a

leak past the gate valve in the city supply.

Those who witnessed the test were quite convinced that the failure of the gravity tank supply to follow in after the pressure tank was exhausted was due to an air lock in the dead riser, for as soon as it was vented in the manner indicated, the gravity tank supply began to function.

A second test was held on April 11th, 1921, in a ten story building of fire resistive construction, with pressure tank and city supplies, the former feeding the dead riser at top and the latter at bottom. It was not expected there would be an air lock under such arrangement and none developed. To save space, details of test are omitted.

Chicago Tests

May-June, 1921.—Conducted jointly by the Central Actuarial Bureau, Chicago Board of Underwriters of Chicago and the Underwriters' Laboratories; reported by J. H. Brumbaugh.

Two horizontal 4,500 gal. total capacity 6′ x 20′ 6½″, 11½″ dish pressure tanks, total length 21′ 6″, 2′ 6″ above roof and check valves, 15′ 1″ above ½″ test orifice on top floor. Water gage glass provided to obtain readings of various levels and pressure gage provided at check.

Two 11,000 gal. 13′ 1½″ diameter x 12′ stave gravity tanks elevated 22′ above top line of sprinklers under main roof. Water level 31′ 2″ above check valve and 42′ 11″ above ½″ test orifice on top floor. Pressure gauge installed at check.

Building ten stories and basement, 140′ basement floor to roof.

All tanks discharge into a common tank drop to basement; sprinkler risers lead up from underground in basement; check in each pressure tank connection above roof and one check for the two gravities above roof. Gravity and pressure tank checks at same level.

Note: Only one pressure tank and one gravity tank used at time of test; one pair of tanks shut off while filled for emergency service. Pressure tank drained through 1½″ drain connection until nearly empty, after which ½″ test connection on top floor draining to sink was used.

Test No. 1 — May 26, 1921.

Water Level	Pressure Tank Pressure	Pressure Tank Pres. at Check Valve	Grav. Tank Press. at Check Valve	Press. at Base of Riser Undgd. Side	Press. at ½″ Test Orifice	
45¾″	85		13.5	145	93	2/3 line
40″	60					
35″						No reading possible
30″	38					
25″	32.5					
20″	28					
15″	24					
10″	20.5					
5	19.5					
0	18.5					Pressure tank empty
		17.5	13.5	60#	0	Air lock developed and water stopped running.

Note. System drain at base of riser opened and pressure in riser at base reduced to 14# at which time gravity tank cut into service. Pressure on pressure tank gauge at check valve when gravity cut in 12¾#; gravity pressure at check 13½#.

Test No. 2 — May 27, 1921.

Water Level	Pressure Tank Pressure	Pressure Tank Pres. at Check Valve	Grav. tank Press. at Check Valve	Press. at Base of Riser Undgd. Side	Press. at ½" Test Orifice	
45¾"	75		13.5	135	83	Water at 2/3 line and normal air pressure.
40"	54					
35"						No reading possible
30"	34					
25"	29					
20"	25					
15"	22					
10"	19					
5"	18					
0	17					Pressure tank empty
		16	13.5	60	0	Air lock developed and water stopped running.

NOTE. Air pressure in tank and tank drop reduced to 12¾# at which time gravity tank cut into service; gravity pressure at check valve 13½# when tank began supplying water to ½" test orifice.

Test No. 3 — June 1st, 1921.

This test was made to ascertain what air pressure and what water level could be carried in pressure tank to guarantee a supply of water from gravity tank. Pressure tank was first drained to bottom and then air was drawn off to 10½# at pressure tank gauge at check which pressure was three pounds less than pressure from gravity at check. Pressure tank was then filled with water and when water reached the two-thirds line air pressure on gage on tank stood at 61#. Pumping was continued until water stood at the 50" level, at which time gauge on pressure tank registered 81#. Regulation air lock test as follows was then conducted.

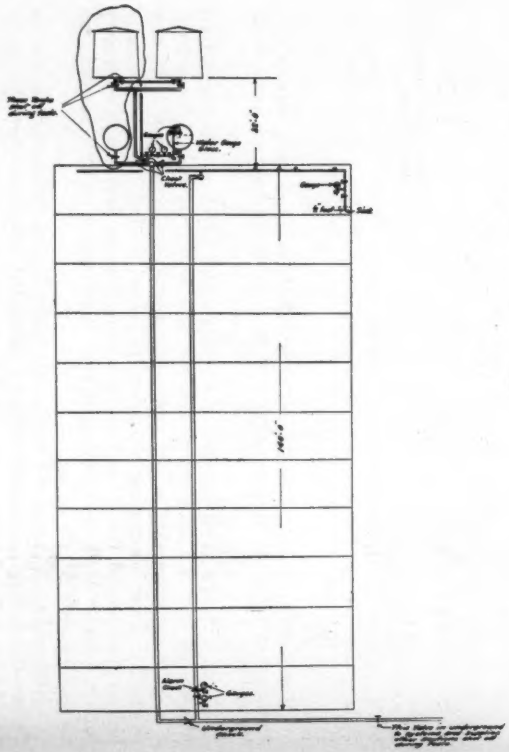
Water Level	Pressure Tank Pressure	Pressure Tank Pres. at Check Valve	Grav. Tank Press. at Check Valve	Press. at Base of Riser Undgd. Side	Press. at ½" Test Orifice	
50"	81		13.5	141	89	Water 4¼" above normal water level
45¾"	56.5					
40"	40					
35"						
30"	27					
25"	21					
20"	17.5					
15"	15					
10"	13.5					

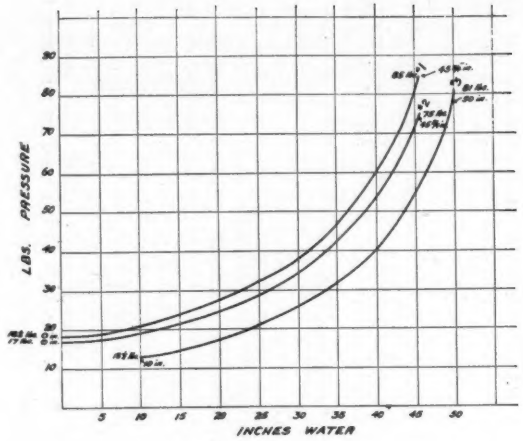
NOTE. Water remained stationary at 9" above pressure tank bottom with a pressure of 12¾# at which point gravity tank cut in and supplied water to ½" test orifice.

You will observe that with a normal water level and a normal air pressure of 75# we obtained a lock out of the gravity tank. Therefore, it may be expected that a lock out might prevail in connection with any risk under normal operating conditions provided the building is sufficiently high to give enough static head in the system riser to overcome the gravity tank pressure. Each test indicated that there was a ¾# differential in the gravity tank check valve.

You will note in test #3 that when water in the pressure tank was at the two-thirds level, a pressure of 61# prevailed, whereas when the water was drawn off, with the water at the same level, a pressure of 56½# prevailed. It would seem that air is absorbed to some extent.

From test #3 we deduce that as a temporary expedient, in order to guarantee the appearance of water at all sprinkler heads, in old equip-





NATIONAL FIRE PROTECTION ASSOCIATION

COMMITTEE ON AUTOMATIC SPRINKLERS

Sketches to Accompany Chicago Tests

NO SCALE

ments, it will probably be safe to empty the pressure tank and then reduce the air pressure if necessary to a point about 5# below the pressure which prevails at the check valve in the gravity tank connection and then fill the pressure tank with water only, and when the water has reached the 2/3 line the safe working air pressure will be automatically determined. However, if a higher working pressure would seem to be in order, it would be advisable to continue raising the water level until a pressure of 75# or 80# was obtained.

We would further recommend that after the pressure tank has been filled with water to the desired level, it be allowed to remain undisturbed for several hours to permit of a reduction in pressure on account of absorption and that at the end of this period the final safe working pressure be determined. In the case of the tanks above mentioned, we found that we had a safe working pressure of 81# with the water at the 50" level, which level was 4¼" above the normal 2/3 water level.

Other members of the Sprinkler Committee witnessing these tests were Mr. Whitney representing Mr. Clarence Goldsmith; Mr. Benjamin Richards, Mr. Denly representing Mr. R. L. Rumbaugh and Mr. Fitzhugh Taylor representing Mr. R. W. Hendricks. The Chicago Board of Underwriters' through Mr. W. D. Matthews and Mr. A. H. Barry co-operated to make the tests possible and assisted at the tests.

The Grinnell Company very kindly donated the material and labor necessary to put the equipment into proper condition for test purposes.

New York Tests.

May, 1921.—Conducted by the New York Fire Insurance Exchange, and reported by E. P. Boone.

It has been found by experiment that the question of excess pressures in pressure tanks without corresponding excess water in the tank is one of importance. As ordinarily designed a pressure tank holds in its cylindrical length when filled to the 2/3 mark very nearly 1/3 of its volume in air, 2/3 water; so nearly, that if water were drawn from the tank the air pressure would decrease according to law of gases expanding at constant temperature rules (noted in Crosby-Fiske-Forster Handbook). When experiments are made with pressure tanks the volume of the spherical ends must be taken into consideration and calculation altered accordingly.

For example: A 7,500 gallon pressure tank, 7 ft. diameter x 26 ft. long:

	Volume	Air	Water	Ratio
For cylindrical length.....	7500	2500	5000	3:1
For total capacity.....	7770	2570	5200	3.025:1

The small difference in the ratios means a deficiency of say 20 gallons of air at 75 lbs. from the calculated amount of 7770/3 = 2590 gallons, and this deficiency at 75 lbs. results in a figure 60 gallons less when the air in the tank shall have expanded to say 15 lbs; and while small in amount has a decided affect on an experiment designed to produce an "air lock" or condition of equilibrium in the sprinkler system.

To calculate the volume of spherical ends of pressure tanks the following formula is used:

Volume each end in gallons $= (\pi = 3.1416) \times$ (diameter tank in feet) $^3 \times 1/8$. Formula holds for standard tanks only with diameter of tank equal to radius of spherical end. $V = \frac{\pi \times D^3}{8}$

In estimating total air capacity of horizontal tanks with water at 2/3 level, it is estimated that ¼ volume of spherical end is filled with air.

Arrow mark on heads of tanks marks the 2/3 full level for the cylindrical section of the tank. The ratio of air to total volume of the tank when water is at this level must be figured for each special case, the position of the tank, horizontal or vertical, being taken properly into consideration.

For example:

For horizontal tank, $7' \times 26'$, ratio = 1.000/3.025.

For vertical tank, $9' \times 15'\ 9''$, ratio = 1.000/2.905.

(Both tanks are labelled 7500 total capacity).

The condition of equilibrium or "air lock" has been reproduced experimentally in systems having pressure and gravity tank supplies with dead riser connecting to base of live risers, at initial conditions of pressure and water in pressure tanks approximately those prescribed by rules, such as water level slightly low and air pressure slightly above 75 lbs. Each sprinkler system with dead riser, pressure and gravity tanks, has its particular conditions which can produce the "air lock," depending on these factors:

a. Elevation of gravity tank above the check in gravity tank discharge.

b. Capacity of pressure tanks.

c. Size and length of pipe (capacity in gallons of pipe) connecting the tanks with the base of live riser.

An "air lock" occurs when the pressure tank or tanks in discharging have sufficient air to blow all water from the tanks and down the dead riser to a level below that in the live riser an amount equal to (or greater than) the head of water from the gravity tank to the check valve without reducing in pressure below this head from the gravity tank.

This condition can be produced when sprinklers operate at various levels in the live riser, the lowest level being the distance above the base of the live riser equal to the height of gravity tank water above its check. Below this point the air lock is not possible. Calculation will show what initial pressure in the tank will be needed at 2/3 full to produce this condition, for an existing system or a supposed system.

Experiment has proven that with small flows a sprinkler system will act in the calculated way, and though no experiment was made with large flows it is probable that the ordinary rules of water and air pressures would hold.

The following arrangements obviate possibility of "air lock":

a. Systems having live risers less in height than elevation of gravity tank water above the check valve.

b. Systems with separate dead risers for pressure and gravity tanks.

c. Arrangement for automatic releasing of air from pressure tanks when pressure shall have reduced to 15 lbs.

d. Maintaining of pressure tanks so that when last water leaves the tank, air pressure is practically zero.

In addition to the possibility of air lock produced by excess air in the pressure tanks, there has been found by experiment to be a possibility of air trapped in the dead riser (by filling the pipes without venting); this air residing in the top of dead riser and expanding when pressure becomes low to a point where it can prevent the proper opening of the gravity tank check valve; this air will be in effect the same as excess air in pressure tank, and steps should be taken to avoid presence of this air. An inspector's test valve is suggested for top of dead riser for this purpose.

Attention is invited to the following table which serves to indicate that low water is a condition as dangerous as excess pressures:

Equivalent Pressure at 2/3 level of 75 lbs. with low water, 7500 gal. pressure tank.

Low	*Total Gal.*	*Gal. Air*	*Compressed to 2/3 level*
1″	7770	2680	79.1
2″	7770	2790	82.9
3″	7770	2900	86.8
4″	7770	3010	90.6
5″	7770	3120	94.4
6″	7770	3230	98.0

It is also calculated that with the pressure tank two-thirds full of water and initial air pressure of 75 lbs., it requires approximately 3 lbs. additional air pressure in the tank to cause locking condition for each 2.3 feet increased elevation of gravity tank.

Recommendations.

1. Pressure and gravity tanks should be connected to system by separate dead risers; or pressure tanks should be connected to top of live riser, and gravity tanks to the bottom of the live riser (or vice versa).
2. Properly elevate the gravity tank so that last of water in pressure and gravity tanks shall be exhausted at same time.
3. Maintain pressure tank at standard condition fixed at 60 lbs. air pressure and eight-tenths full of water with gauge glass rearranged to suit, so that last water will leave pressure and gravity tanks at the same time.

Criticisms of Other Proposed Arrangements.

a. Small pipe connecting tops of live and dead risers; this would allow delays because of large amount of air required to escape.

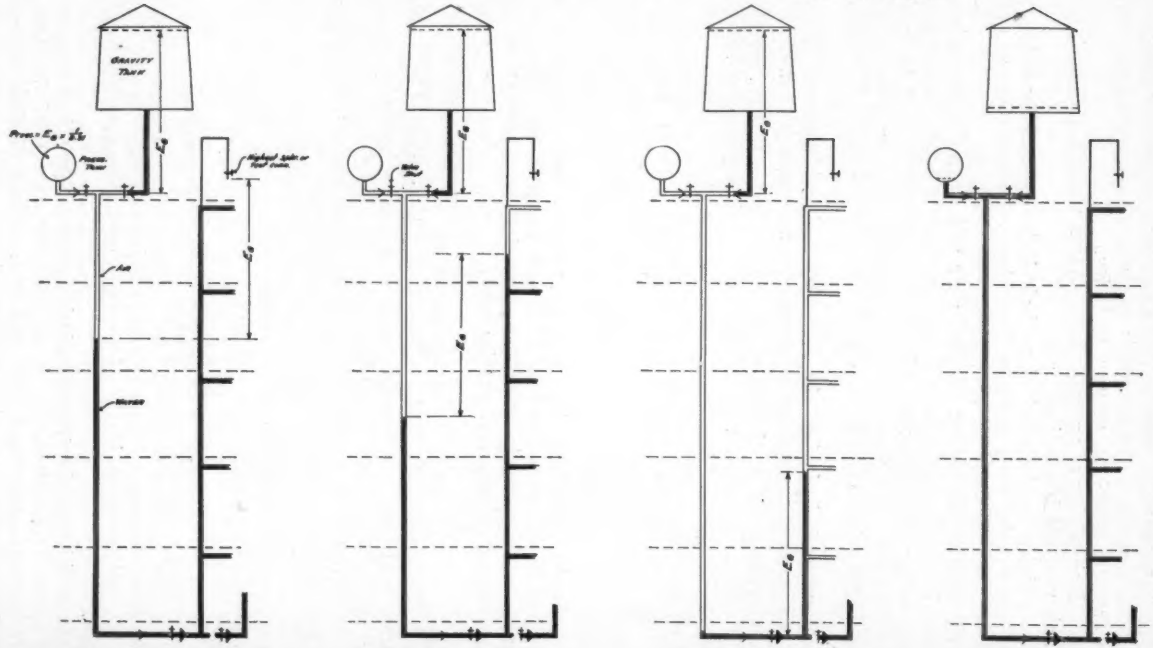
b. Ball cock on inside of pressure tank: Inaccessible for repairs or test.

In addition to the recommendations noted above, it is recommended that a vent (not automatic) be provided for the top of the dead riser; a 1/2 in. valve and plug will be sufficient. This will allow air to be removed from top of dead riser immediately after filling system. It seems to be a tendency of air trapped in dead riser to slowly disappear, possibly

SKETCHES SHOWING ACTION OF AIR IN DEAD RISER

TO ACCOMPANY REPORT OF TESTS BY N.Y. FIRE INSURANCE EXCHANGE

New York City, May, 1921.


GRAVITY TANK
Press. Gage
Air
Water
Equilibrium in System with highest water pressure possible at pressure tank.
Equilibrium in System refilled by gravity tank without venting dead riser
Maximum portion of System without automatic supply from gravity tank due to 95# from pressure tank and 3' low water.
System designed for both tanks to supply at about same time.

through stuffing boxes, and pipe joints, tight against water but not air tight.

The following paragraphs give in brief detail the tests made on specimen equipments. They indicate that the action of sprinkler systems can be predicted with reasonable accuracy.

Test at Property No. 1

It was found by experiment with a test connection from sprinkler line in top of stair enclosure extending to roof that:

a. A small excess pressure above 75 lbs. in pressure tanks with water at 2/3 level will cause a condition of equilibrium in this system (no water flowing) with test valve and all control valves open, with pressure tanks and upper section of dead riser filled with air at slightly above 15 lbs. and gravity tank full.

b. The dead riser drained, filled with air at atmospheric pressure, when water is turned on again will hold an amount of air at 15 lbs. (from gravity tank) or 25 lbs. (from pressure tanks) which expanding under lighter pressures will cause a condition of equilibrium similar to that above described.

c. Action of the sprinkler system can be computed in advance as the changes of pressure are gradual and slow. Each sprinkler system has its own set of critical conditions, depending on elevation of gravity tanks, capacity of pressure tanks, capacity of dead riser including connections from tanks.

Calculations.

Elevation of water in gravity tank (full) above the check — 34 ft. Equivalent to pressure of 14.7 lbs. Elevation of water in gravity tank (empty) above the check = 18 ft. 8 in. Equivalent to 8.1 lbs.

To produce "air lock" at top line of sprinklers with gravity tank full it is necessary to have pressure tanks full of air at 15 lbs. plus the section of dead riser above a point 34 ft. below top lines of sprinklers.

$$\begin{aligned} \text{Capacity 2 pressure tanks} &= 15.540 \text{ gallons—} \\ \text{Capacity upper section dead riser} &= (19\ 1/2 \times 1\text{-}1/2 \text{ plus } 34) \times 1\text{-}1/2 \text{ (gal/ft.)} \\ &= 80.25 \text{ gal.} \end{aligned}$$

Necessary initial pressure in pressure tanks to lock water from top lines =

$$P = \frac{(15.540 + 80.25) \times (14.7 + 14.7)}{5140} = 89.6 \text{ lbs. Abs.}$$

$$= 74.9 \text{ lbs. gauge.}$$

Actual Tests.

a. System found: Gravity tank full. Pressure tanks 2/3 mark, 74 lbs. by test gauge. Water discharged from pressure tanks by emergency drain to 15 lbs. approximately, remainder through test connection. Result: continual flow until noted that water was coming from gravity tank in proper manner at rate about 12.5 gal. min. No locking developed. Evidently because working conditions found were not within the limits necessary to produce the air lock.

b. Water shut off and dead riser drained to attach gauges at top and bottom, — refilled to 14-1/2 lbs. at top, using gravity tank: 45 lbs. at the bottom. Result: enough air was trapped in top of dead riser to hold gravity tank check valve closed with all control valves open except at pressure tanks.

c. Air trapped in test "B" was compressed to 60 lbs. by water from reserve pressure tank — then allowed to expand by opening the test valve. Flow noted until trapped air pressure was reduced to 16-1/2 lbs. when flow stopped. No water came from gravity tank.

d. An empty pressure tank was filled to 17-1/2 lbs. with air, then partly filled with water. (All air was released from top of dead riser, Test "C"). With gravity tank valve and test tank (pressure tank) valve open flow was noted from test connection until air was 16-1/2 lbs. when flow stopped. No water came from gravity tank.

Test at Property No. 2.

It was found by experiment with test connection from sprinkler lines in pressure tank house that an air lock in this system in working condition is strongly possible

a. Air in tank was 93 lbs., water at 2/3 full mark. Water was drawn from pressure tank by emergency drain until nearly empty; remainder through test connection. There was continuous flow from gravity tank after pressure in pressure tank was sufficiently reduced.

b. Dead riser was drained to attach gauges at top and bottom. Dead riser was refilled from gravity tank without venting, trapped sufficient air to prevent flow from test connection.

c. Having calculated required pressure to lock system as 75.3 lbs. in pressure tank, water at 2/3 full mark, a test was started with 76 lbs. in pressure tank, water at 2/3 full mark. Water drawn as in test "A." Flow stopped when pressure of air in tank and dead riser had reduced to 15.4 lbs.

d. Air was partly released from dead riser and tank, and flow recommenced at 14.4 lbs. air pressure.

Test at Property No. 3.

System as found by inspectors showed water in pressure tank 1 in. high and pressure below 75 lbs. Knowing that this condition could not produce the air lock, test was made to determine whether air was residing in down pipe. Test valve connected to sprinklers in pressure tank house.

a. Pressure tank shut off. Test valve opened, noted continuous flow from gravity tank.

b. Down pipe drilled and tapped to attach gauge — noted no air in down pipe.

c. After gauges were attached system refilled from gravity tank — did not trap sufficient air in top of dead riser to prevent continuous flow from gravity tank through test valve.

d. Started with 80.5 lbs. in pressure tank 2/3 full. Tank partly emptied by emergency drain to 18 lbs. pressure. Test valve opened. Flow stopped at 17.3 lbs. in pressure tank, no water coming from gravity tank. Some air released from top of dead riser allowed water to start from gravity tank when reduced to 15 lbs.

ADDRESS AND NAME (OMITTED AND GIVEN BY NUMBER)	ELEV. WATER IN G. TANK ABOVE CHECK VALVE		CAPACITY, GALS. OF DOWN PIPE ON TEST PL.	VERTICAL HEIGHT OF DEAD RISER	CAPACITY OF PRESSURE TANKS	CALC. LOCKING PRESS. IN TANKS AT ¾ FULL	TEST PRESSURES IN PRESS. TANKS		REMARKS	VERT. HEIGHT FROM TEST VALVE TO D.R. BASE	PART OF SYSTEM THAT CAN BE LOCKED WITH INITIAL CONDITIONS 3" LOW & 85# IN PRESS. TANKS.	CALC. MIN. INITIAL PRES. TO LOCK 34' ABOVE BASE OF DEAD RISER.	RATIO AIR TO TOTAL TANK CAP. WITH WATER AT ARROW
	FULL	EMPTY					START	FINAL					
	Ft.	Ft.	Gal.	Ft.	Gal.	Lbs.	Lbs.	Lbs.		Ft.		Lbs.	
TEST AT PROPERTY #1.	34	18.6	29.2	113	Two AT 7770	74.9	74 82.1	14.6 15.5	NOT LOCKED LOCK RESULTED	111	ALL ABOVE 34' UP FROM BASE OF DEAD RISER.	74.7	1.000 3.025
TEST AT PROPERTY #2.	34	23.5	35.5	80.6	ONE AT 7770	75.3	75 76.	14.6 15.4	NOT LOCKED LOCK RESULTED	82.2	ALL ABOVE 34' UP FROM BASE OF DEAD RISER.	75.4	1.000 3.025
TEST AT PROPERTY #3.	35.8	28.3	38.2	60.2	ONE AT 7770	78.3	60 80.5	17.3	NOT TESTED LOCK RESULTED	64.	ALL ABOVE 35.8 FT. UP FROM BASE OF DEAD RISER	78.8	1.000 3.025
TEST AT PROPERTY #4	32.7	21.8	40.	132.	ONE AT 8222	69.8	WATER 3 1/16" LOW. 74	17	LOCK RESULTED	136	ALL ABOVE 32.7 FT. UP FROM BASE OF DEAD RISER	71.8	1.000 2.905

IT WILL BE NOTED THAT IN EACH BUILDING EXCEPT AT PROPERTY #4, NO LOCK WAS OBTAINED WITH SYSTEM AS FOUND.

Tabulated Summary of New York Tests.

Test at Property No. 4.

System was found at 74 lbs. pressure and water 3 in. low. A test was made without altering these conditions.

a. Water was drawn down through drains to point approximately 18 lbs. pressure. Test valve above roof was then allowed to discharge remainder of water until flow stopped at 17 lbs. pressure, no water coming from gravity tank.

b. Dead and live risers were drained and refilled from gravity tank after attaching gage to top of dead riser. Enough air was trapped to prevent water reaching the test pipe. Dead riser 2 in. drain was opened and water allowed to flow from dead riser and gravity tank; flow commenced at test valve though not the full flow given by gravity tank pressure. System was then restored to normal.

c. Test "B" indicated that air trapped in dead riser can be partially removed through drain by rapid flow of water. A vent at top of dead riser is required to remove all of the trapped air.

Hoboken Pier Fire.

Report by Chas. H. Fischer.
(Member N. F. P. A.)

Fire broke out at 6:29 P. M. on August 24, 1921 on piers 5 and 6 at Hoboken, N. J. At the time of the fire the pier was unoccupied but was under the control of the War Department.

Construction.

General: Piers 5 and 6 are army piers which were formerly part of the Port of Embarkation at Hoboken and were known before the war as Piers 2 and 3 of the Hamburg American Line. They are connected on the bulkhead by a frame bulkhead building. They are adjacent to the D. L. & W. ferry on the north, and have a 175-foot slip between them; Pier 5 is separated from Pier 4 on the north by a 250-foot slip. *Height*—One-story equals 34 feet. *Area*—Pier 5, 72 x 740 feet, area 53,280 square feet; Pier 6, 45 x 716 feet, area 32,220 square feet; bulkhead building, 105 x 380 feet, area 39,900 square feet; total area 125,400 square feet; all forming one structure. *Walls*—Frame, weather-boards one-inch wide on 3 x 12 studs except that west wall is iron clad. *Floor*—4 x 12 plank on heavy timbers on wood piles. (The pier deck, which forms first floor is open on all sides between the string pieces and the water line). *Roof*—Gravel and composition on one-inch boards on wood trusses with tie rod construction on built-up wood columns. *Skylight*—Of frame construction, monitor type, with thin glass sides; on each pier the skylight is 10 feet wide and 6 feet high and extends practically the entire length of the pier. On the bulkhead building there are two skylights of similar construction 12 x 48 feet. *Offices and other interior structures*—Inside of the piers and the bulkhead buildings there are a number of one and two-story frame or frame and iron clad structures used for offices and other purposes. *Partitions*—The bulkhead is divided into approximately three equal parts by two partitions; constructed of two thicknesses of one-inch D. & M. boards on 2 x 4 studding. *Communications*—The bulkhead building communicates on the west through a large opening protected by poor fire door with one-story machine shop.

The pier was equipped with electric incandescent lighting which was entirely overhauled and placed in conduit during the war period. Some twelve or fourteen electric wenches were installed. The wiring to these and the wenches themselves were entirely overhauled during the war period.

Fire Protection.

Private fire protection consisted of an ample supply of casks and pails and an inside standpipe system supplied from the municipal water system which has a pressure of about 45 pounds in the mains at all times; in addition there is a 1500 gallon fire pump installed in a fire resistive boiler house a short distance away.

This pier was inaccessible to land apparatus. Fire boats prevented spread to other piers and vessels.

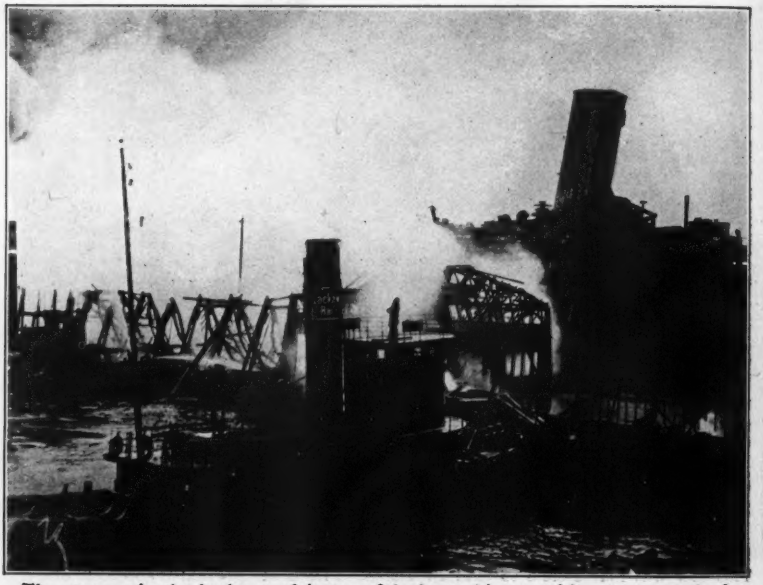
There are an ample number of public fire hydrants within 800 feet of these piers. Land fire fighting forces consist of the Hoboken Fire Department and aid that could be summoned from Jersey City. On the water end protection could be secured from the marine division of the New York Fire Department and from the numerous tugs of the various railroad companies which have pumps installed at capacities ranging as high as 1500 gallons per minute.

Origin of the Fire.

The fire was discovered by the watchman in the pier shed about 40 feet from the water end. No definite conclusion has been arrived at regarding the cause of the fire but two theories are advanced, one is that it was electric wiring, and the other that the fire was caused by a cigarette butt.

Upon discovery of the fire the watchman rushed to the shore end and sounded an alarm. The apparatus of the Hoboken Fire Department, about three blocks distant, responded immediately. When the hose lines were laid into the pier the firemen found that from the shore end the pier was inaccessible and untenable on account of the wave of intense heat and dense smoke. Immediately upon arrival the chief of the fire department set in a general alarm and summoned aid from Jersey City and also summoned the New York fire boats.

The Hoboken Fire Company had in operation six engine companies, two spare engines and two truck companies; the Jersey City Fire Department had four engine companies in service; the New York Fire Depart-



The steamer in the background is one of the large ships saved by prompt work of the fire fighters.

ment responded with three fire boats and about ten tugs. The land forces used about twenty-four streams with nozzles ranging from 1-1/8 to 1-1/4 inches. The New York fire boats each served with two deck pipes and one with six streams, the various tug boats used one or two streams, and in several instances deck pipes. Pressure recording gauge at fire department headquarters, three blocks distant, showed that the pressure on the system never was below 20 pounds and ranged as high as 40 pounds which should have insured an adequate supply of water to all the engines that were drafting from the mains.

Loss.

The fire destroyed Pier 5 and a considerable part of the bulkhead building extending partly into Pier 6; about 100 feet of the shore end of Pier 6 was seriously damaged. No definite figures are available at this time regarding the loss but it is estimated by the Hoboken authorities that the loss is about $500,000 on the structure, contents none. Loss on vessels in the slip was very slight. It is interesting to note that the steamship *Leviathan* was berthed on the south side of Pier 4 across the slip from Pier 5 on which the fire originated. The damage to this was comparatively slight but largely due to the fact of the assembling of such formidable fire fighting facilities. On the north side of Pier 4 the steamer *Wheaton* had 1000 bodies of our soldiers and Pier 4 had 4700 bodies.

Warner-Quinlan Asphalt Company Fire.

Report by Garrett B. James.

(Member N. F. P. A.)

The Warner-Quinlan Asphalt Company suffered a $3,000,000 loss due to fire which started in their plant near Linden, N. J., at about 2 P. M., July 18th, 1921. The exact origin of the fire is not known, but it is thought that it was caused either by an explosion of an overheated still, or when an attempt was made to burn off a connection of a fuel oil tank near the boiler house.

The Fire.

Following the first explosion, the boiler house went up in flames. Under Superintendent Charles Almquist the fire force of the plant was mobilized, but before they could reach the firehouse it too was in flames. According to good authority the first explosion and the resulting fire put out of commission every piece of fire-fighting equipment at the plant.

Fire soon spread to the office building, the laboratories, and the storehouse, where 3000 bbls. of crude oil were added to the blazing oil and asphalt which was then sweeping through the plant. Lines of hose were dragged from buildings not yet attacked, but as the men were forced to retreat, due to the intense heat, the hose was burned. The fire departments from Linden, Elizabeth, Perth Amboy, and Rahway responded to the alarm, but there were few hydrants in the vicinity and the water, from those available, was of little service. For a time it was thought that streams of water might result in saving some of the more distant tanks and stills, but it was too hot for the firemen to remain at their posts as the fire leaped from tank to tank among the thirty-odd tanks and stills on the asphalt plant side of the railroad tracks. Several tank cars of crude oil were burned while standing on the siding; other cars were hauled off before the flames reached them.

As the asphalt and oil began pouring over the fields and meadows, steps were taken to stop this flood and protect adjoining property. Trenches were dug and dikes thrown up on all sides of the plant except the north, where it was impossible to get within several hundred feet of the tanks, owing to the strong wind from the south and southwest. Among the nearby plants were the Sinclair Consolidated Oil Company, (under construction); Grasselli Chemical Co. (across the Rahway River); American Cyanamid Company (adjoining), and the Bayway Plant of the Standard Oil Company of New Jersey. From the last mentioned plant portable fire foam equipment was hurried to Linden to aid the fire-fighters then at work.

Fire Prevention Methods.

Early in the evening, the oil surface in two 55,000 bbl. (114 feet in diameter) steel tanks was blanketed with fire foam from the portable equipment in an effort to save them from destruction. A seam, near the

Photograph by U. S. Army Air Service

An airplane view of the fire shortly before it spread over the water.

bottom of one of the tanks, sprung open, due to the heat, allowing the contents to flow out on the ground. A raging fire ensued until the fire foam blanket, which was over the surface of the oil, began to flow out. This extinguished considerable burning oil on the ground around the tank, while the fire foam blanket saved the other tank intact with its contents.

Fire at Waterfront.

At about 10 P. M., of the 18th another tank exploded adding to the flaming oil which was spreading toward the water's edge. A steamer at the company's dock was set adrift to save it from the flames which were quickly communicated to the dock, where many barrels of oil added to the fire. Blazing oil poured out over the dock and into Staten Island Sound, where the water became a sea of flame. The fire tug "Mayor Gaynor," from New York, two of the Standard Oil tugs and one of the Warner-Quinlan Company's boats fought the onrushing flames in order to keep them from spreading down the Sound to many industrial plants and forty vessels of the United States Shipping Board which were moored

nearby in the harbor at Prall's Island. The efforts of fire tugs were of little avail until a system of wooden booms was constructed and towed into positions where they formed a barrier against the spread of the burning oil. These booms soon ignited, but with their aid and the aid of the wind and tide, the spread of the oil over the water was checked.

Spread of Fire to Refinery.

Early in the morning of July 19th, one of the large asphalt oil storage tanks burst carrying the fire across the railroad tacks into the refinery side, or western part of the plant, which up to that time had been preserved from damage. This was followed by the explosion of six smaller tanks of gasoline and caused firemen to abandon their hose lines in order to save other fire apparatus from destruction.

By noon of the 19th, only company employees were fighting the fire with the portable fire foam equipment from the Standard Oil Co. An effort was being made to check the spread of the flames on the west side of the tracks. At 3 P. M. the wind freshened and changed in direction and in spite of all efforts burning oil spread towards a group of gasoline and oil tanks still standing on the west side of the plant. One of the gasoline tanks had been emptied but the oil set fire to one of the filled tanks and it was soon consumed.

Fire Extinguishing Methods.

At 4 P. M. the Standard Oil Company's portable fire foam equipment was in service, piping fire foam (a practice which has generally been abandoned in favor of piping solutions) a distance of about 250 feet through 2 1/2-inch hose and into a bent pipe supported over the remains of a tank which had previously burned. Most of the fire foam was falling on the ground and what did reach the fire was of little use. As foam had been delivered in this manner, through one line for several hours, it was decided to arrange to apply it more rapidly. Another hose line was laid from the pump, piping foam about the same distance but delivering it to the oil tank through a nozzle from the ground. The fire was not subdued very readily, and after applying foam in this manner for about 15 minutes the solutions were exhausted. It was then decided to secure additional solutions and apply foam through a nozzle from the roof of a nearby gasoline tank. Two tank cars of chemical solutions were secured and while attempting to connect these to the pump, the fire spread very rapidly over considerable area, on the asphalt plant side of the railroad tracks, so it was necessary to remove the fire foam equipment to a place of safety. This ground fire was put out with water.

After about two hours' delay, the foam equipment was connected and Supt. Charles Almquist with his brother went up on top of a nearby gasoline tank and applied the foam into the burning crude oil tank from the nozzle. Previous to this, water was applied to cool the gasoline tank. The fire was then extinguished with fire foam in about twenty minutes, there being a small portion where the tank had buckled where the oil persisted in burning. A severe electrical storm was raging, although it did not rain very hard. Finally the flames from the oil tank went out, but dense clouds of vapor continued to be emitted from under the fold in the tank. These vapors flashed at least eight times. About the time

of the fourth flash, the foam started to roll out of the tank, and it was clearly noticed that the oil was beginning to boil. The boiling decreased as the tank cooled.

This tank was on the refinery side of the railroad tracks, and was one of the congested group of small tanks. It was about 25 ft. in diameter and 30 ft. in height. The tank had been burning since noon and when extinguished, the oil level was 20 ft. from the top. A heavy rain fell during the evening of the 19th, minimizing the danger of a grass fire spreading over the salt marsh to surrounding property.

On the morning of the 20th of July there was left on the four acre tract east of the railroad tracks, one large crude oil tank, a small crude oil tank, two small asphalt tanks and two small receiving tanks. On the one acre west of the tracks there remained four lubricating oil tanks, one crude oil tank, two gasoline tanks and four smaller tanks. These remaining contained 102,000 bbls. of various kinds of oil or other material. More than 200,000 bbls. of oils were lost in the seventeen oil tanks and fourteen asphalt tanks that were destroyed.

Conclusions.

There are three lessons that can be learned from this fire.

First: All oil storage tanks should be surrounded by permanent dikes of suitable size to confine any oil which may be splashed or leak from the tank during a fire.

Second: All oil properties should be protected with suitable equipment for extinguishing large oil fires. This will not only minimize the loss, but will avoid the menace of "boiling over" and its conflagration hazard. Portable equipment (on account of its limitations) cannot be relied upon to extinguish large oil fires.

Third: The great menace of floating oil on harbor waters is again emphasized.